SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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OCTOBER 1956—VOL. 28, No. 10

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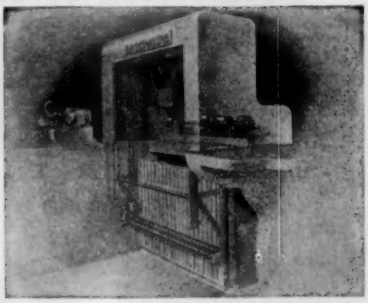

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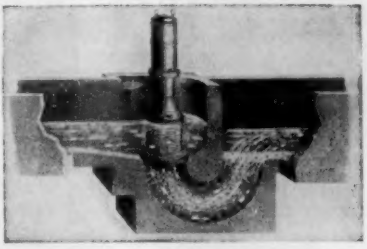

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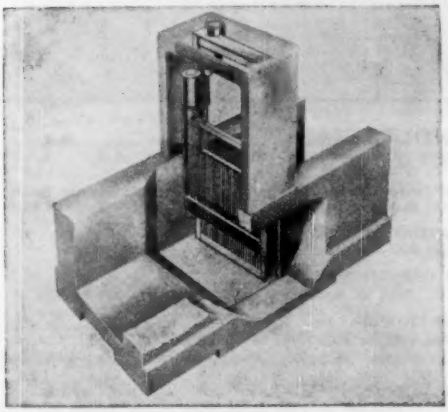

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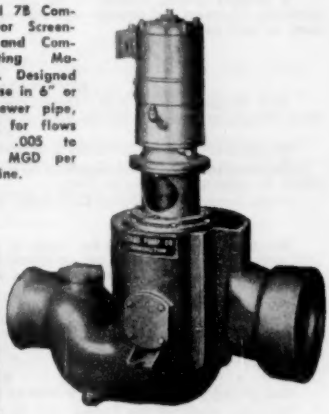

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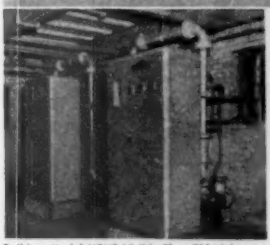

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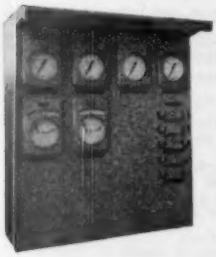

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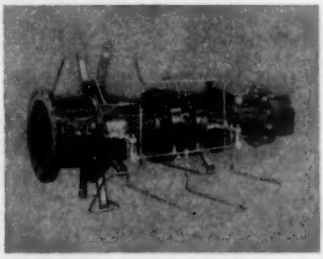

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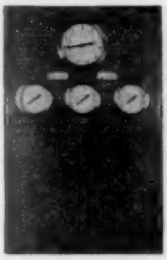

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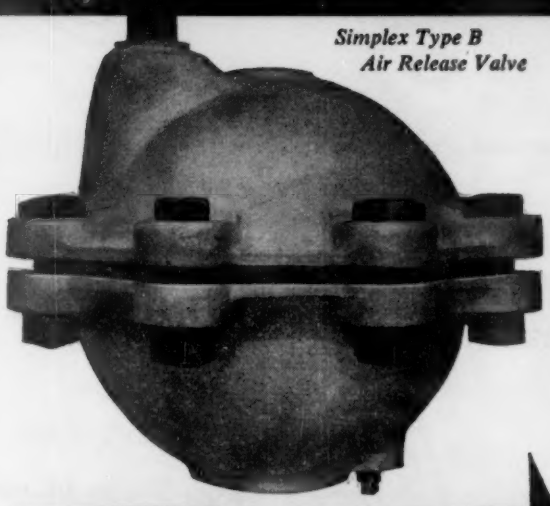

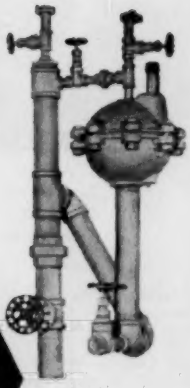

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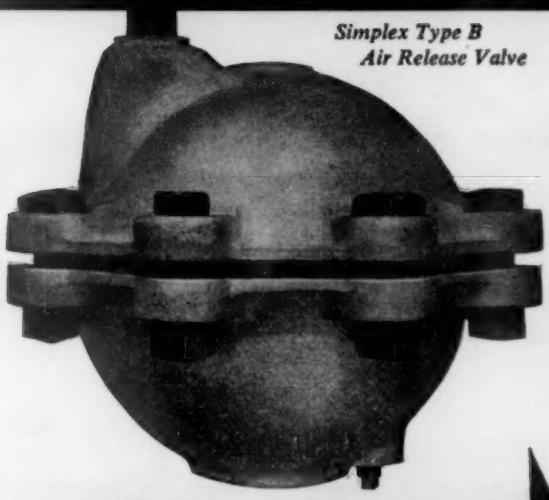
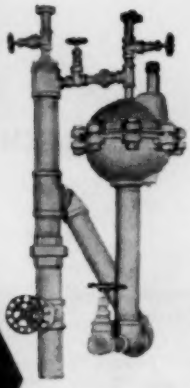
Air Release Valve





One 2" connection to your sewage main

cuts pumping costs

Here's the low-cost way to reduce the high costs of pumping sewage. The Simplex Type B Air Release Valve rids lines of entrained air and sewage gases . . . puts an end to binding at high points. It quickly pays for itself by lowering the friction head, increasing pumping capacity. **How you save!** When air and gases collect in the upper valve shell, they depress the rugged ball float . . . automatically opening the needle valve so that all entrained air and gas escape *immediately!*

CHECK THESE ADVANTAGES!

- Reliable! Bronze seat with silicon rubber-tipped valve stem designed to prevent sticking shut or leaking water.
- Rugged! Cast iron shell and non-corrodible float can take pressures up to 250 psig.
- Simple—few parts, just one lever movement.
- Vacuum-holder prevents loss of prime.
- Easy back-flushing with no permanent connection to clear water supply.
- Shipped complete with pipe leg to collect sediment and valve to blow it off.
- Easy to install—just one quick connection.

WRITE FOR BULLETIN 1204
Simplex Valve & Meter Company, Dept. S-10
7 East Orange Street, Lancaster, Pa.

ACCURATE INSTRUMENTS AND CONTROLS SINCE 1904

SIMPLEX®

VALVE AND METER COMPANY

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Abwassertechnische Vereinigung	Dusseldorf, Germany	Oct. 3–5, 1956
North Dakota Water and Sewage Works Conference	Lewis and Clark Hotel Mandan, N. D.	Oct. 3–5, 1956
Pacific Northwest Sewage and Industrial Wastes Assn.	Boise, Idaho	Oct. 4–6, 1956

TWENTY-NINTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
California Sewage and Industrial Wastes Association
Statler Hotel, Los Angeles, California
October 8–11, 1956

Canadian Institute on Sewage and Sanitation	Prince Edward Hotel Windsor, Ontario	Oct. 29–31, 1956
West Virginia Sewage and Industrial Wastes Assn.	West Virginian Hotel Bluefield, W. Va.	Oct. 31–Nov. 2, 1956
Nebraska Sewage and Industrial Wastes Assn.	Castle Hotel Omaha, Neb.	Nov. 1–2, 1956
New England Sewage and Industrial Wastes Assn.	Hotel Weldon Greenfield, Mass.	Nov. 8, 1956
Florida Sewage and Industrial Wastes Assn.	Daytona Plaza Hotel Daytona Beach, Fla.	Nov. 11–14, 1956
North Carolina Sewage and Industrial Waste Assn.	Charlotte Hotel Charlotte, N. C.	Nov. 12–14, 1956

The percentages are right with

INFILCO *High-Rate* SEWAGE TREATMENT

100%.. ..Faster
50%.. ..Less Space
90-95%.. ..B.O.D. Removal

INFILCO's improved activated-sludge equipment for *high-rate* sewage treatment is the answer to problems of maximum volume from minimum space—highest efficiency at lowest cost.

Complete treatment requires only five to six hours as compared to 10 to 12 hours in conventional plants. Area required is scarcely half as much. Expenses for property, construction, and operation are substantially reduced. And all this without sacrifice in efficiency. Here are typical operating figures from the installation in Collinsville, Okla.—

EFFICIENCY

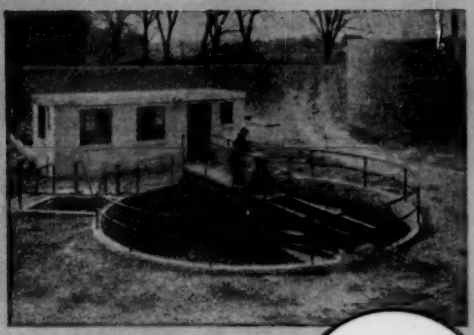
Date	Ave. Flow MGD	Average B.O.D. Raw Sewage	Average B.O.D. Final Effluent	Average B.O.D. % Removal	Suspended Solids Raw Sewage	Suspended Solids Final Effluent	Suspended Solids % Removal
1/14-2/3, '56	.800	287	21	92.7	335	22	98.5

These figures indicate what can be accomplished in treatment of sewage for institutions or small communities. If you have such a problem, consult INFILCO, because

INFILCO KNOWS HOW to help you solve it.

Over 60 years of experience and the most complete and advanced line of equipment are available to you. Write today for full information on the interesting Collinsville installation and Bulletin No. 6550.—SI-26.

Inquiries are also invited on all other water and waste treating problems including coagulation, precipitation, sedimentation, filtration, flotation, aeration, ion exchange and biological processes.



BIOSORPTION® activated-sludge plant for treatment of sewage at Collinsville, Okla.

Consulting Engineers: **WOOD & CRAIG** *Tulsa, Okla.*

COLAFLEX® diffusers

FLOW DIAGRAM: DESIGN AVERAGE FLOW 0.21 M.G.D.

48 **COLAFLEX®** diffusers in mixer-stabilizer

INFILCO

INFILCO INC.
General Offices
Tucson, Arizona

The ONE company offering equipment for ALL types of water and waste treatment.

FIELD OFFICES THROUGHOUT THE UNITED STATES AND IN FOREIGN COUNTRIES

Multiplies Bearing Contact Area by SIX . . . *AT LEAST!*

With Chapman's Beamed Waterway Valve, in the partly open position, you get *six to ten* times more bearing contact surface. That's six to ten times more bearing contact surface than you could get from any other double disc parallel seat or square bottom gate valve. No wonder it leads the preferred list for Filtration Plants, Wash Water Service, or other similar limited throttling use.

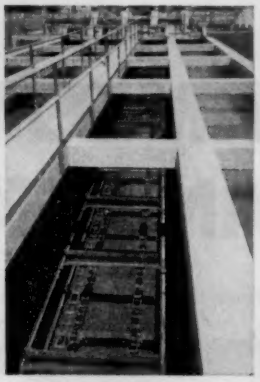
Operation is smooth. They seat snugly. There's little or no leakage. Bronze bearing surfaces on beams and downstream discs are rugged. Their long useful life . . . with top-notch performance and lowest maintenance . . . is measured in decades, not just years. This applies to all sizes . . . with any desired method of operation.

Outside of a stamp, it costs nothing to get all the facts. You'll find them in our Catalog No. 45 . . . an informative digest devoted exclusively to Chapman Beamed Waterway Gate Valves.

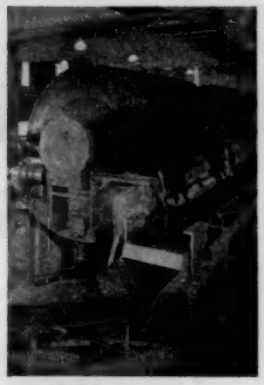
Why not write for it . . . now!

THE CHAPMAN VALVE MANUFACTURING COMPANY
INDIAN ORCHARD, MASSACHUSETTS

PRE-AERATION increases efficiency of 20 tanks equipped with sludge collectors. Air floats grease, flocculates solids and adds dissolved oxygen to the effluent.

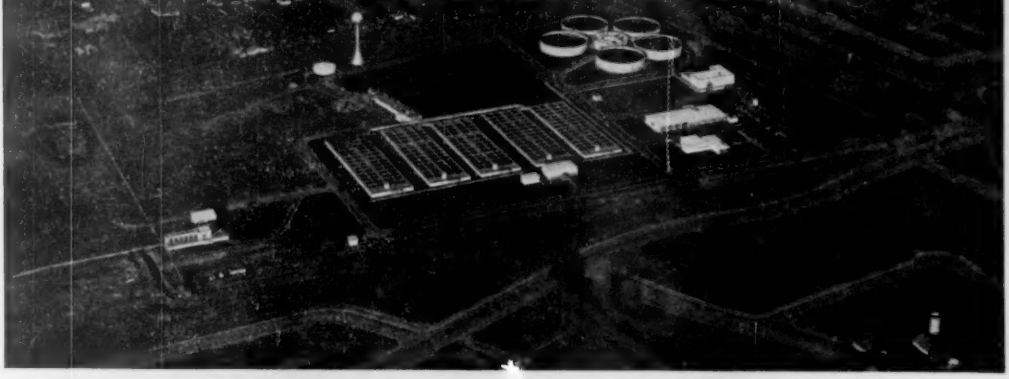


FOUR LINK-BELT grit collectors slow sewage velocity to 1.25 fps . . . and remove grit from lighter solids that remain in suspension.



SLUDGE CAKE is conveyed from vacuum filters by Link-Belt belt conveyors. It is used as "Soil Conditioner" by the City Park, nurseries and home gardeners.

How Sacramento effectively controls ODOR - - POLLUTION - - DISPOSAL



LINK-BELT pre-aeration and sludge removal equipment satisfies rigid water purity standards

SINCE 1949, Sacramento's population and industry have increased 50%. To stop odors and water pollution in the Sacramento River, the city recently installed a new sewage treatment plant equipped with Link-Belt grit collecting and washing equipment, sludge collectors and skimming equipment, and belt conveyors for handling the dewatered sludge. The equipment was included in specifications drawn up by the engineering office of Clyde C. Kennedy, Consulting Engineers.

Link-Belt's complete line of equipment and broad engineering experience provide low-cost, efficient water, sewage and waste treatment for municipalities and industries throughout the country. A call to your nearest Link-Belt office will put you in touch with our sanitary engineers who will work with your consultants and chemists.

14,238

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

6 TIMES MORE THAN WE NEED

MODERNIZED **cast iron**

RAINFALL ...still not enough!

No secret to you that water is America's No. 1 Problem... that rainfall is largely wasted, unevenly distributed or polluted.

But does the public know it?

It's important that the great mass of the American people learn the facts. We're helping there.

Month after month our national advertising stresses the need for long range planning of water facilities; public support for realistic water rates; necessary water works financing; conservation by homeowner and industry.

Our aim... like yours... is to alert the public to the growing seriousness of water shortages... enlist their cooperation so that we—and our children—will be assured of a plentiful supply of water for all our needs.

CAST IRON PIPE

proved by Performance

Over a hundred years ago cast iron pipe mains were laid by more than 70 American utilities. They're still working efficiently.

Here's proof of cast iron pipe's dependability and longevity... its savings in maintenance costs and tax dollars.

Today's modernized cast iron pipe, centrifugally cast for greater strength and uniformity, is even more durable. Where needed, it can be cement-lined for sustained carrying capacity through generations of hard use.

When you specify pipe for your water system, remember: no other pipe can match cast iron's *proved* record of performance. It serves for centuries.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3, Illinois.

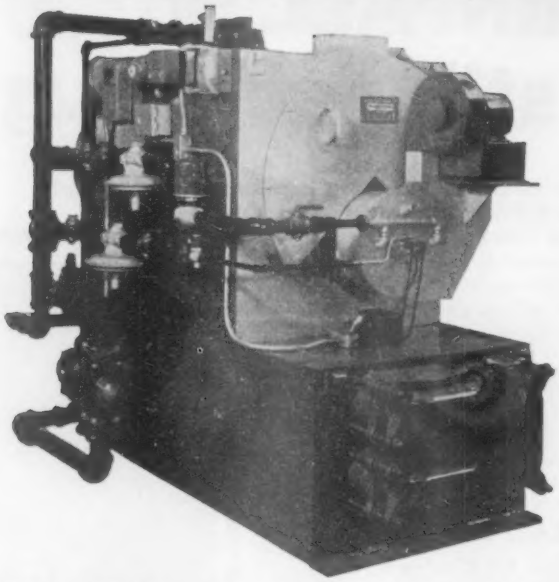
This rugged old cast iron water main, laid 125 years ago, is serving and saving tax dollars for the citizens of Detroit, Michigan.

CAST IRON

The Q-Check stenciled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS

WALKER PROCESS HEATX UNIT
Digester Heat Exchanger



370,000 BTU/hr. HEATX for installation at Villa Park, Illinois. Burner automatically utilizes sewage gas or natural gas separately or in combination. A pre-ignition purge cycle clears the combustion chamber of any fuel accumulation before starting or between fuel switch-over.

FORCED TURBULENT CIRCULATION
HIGH RATE OF HEAT TRANSFER
NO SLUDGE ADHESION

The HEATX is designed to allow absolute and independent control over each function of sludge heating; namely, heating of jacket water, control of temperature and flow of jacket water and control of digester temperature and rate of turnover.

The HEATX is offered as either a separate exchanger, for use with existing standard boilers or as a package unit complete with a Walker Process boiler and burner. Boilers are designed to burn sewage gas, sewage gas and oil or sewage gas and natural gas.

The concentric tube type exchanger is equipped with special removable end castings arranged to prevent contamination of the heating water by material circulated through the sludge tubes.

Write for Bulletin 24S82.

Engineering and manufacturing a complete line of water, waste and sewage treatment equipment.

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
Factory — Engineering Offices — Laboratories
Aurora, Illinois

Giant helicopters . . . atomic-powered and capable of lifting vast tonnages . . . some day may transport homes intact from winter to summer locations . . . enable people to move with a minimum of disorder and effort.

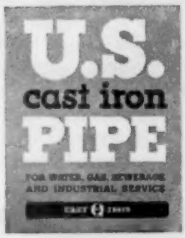
100 years from now...

WE MAY MOVE HOUSES BY AIR!

Many incredible changes in the world of tomorrow. But even then, our water and gas will still be carried by that dependable public servant—the cast iron pipe being laid today.

Records show that cast iron mains installed over a hundred years ago are still serving effectively for more than seventy American water and gas utilities. Moreover, the modernized cast iron pipe of today . . . centrifugally cast and quality controlled . . . is even stronger, tougher, more serviceable.

U.S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.



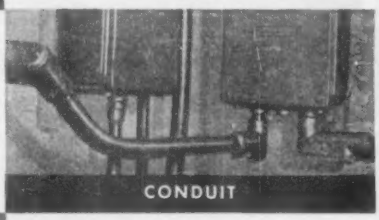
U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham 2, Alabama

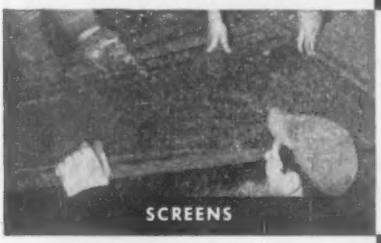
A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.

Proved Protection against Corrosion with EVERDUR

Everdur is Readily Fabricated. Everdur alloys are available for hot or cold working, welding, free-machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

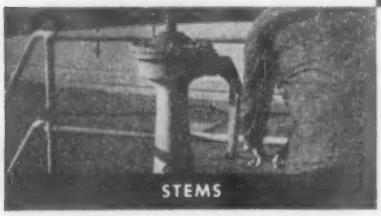
Everdur* Resists Corrosion. Installations of Everdur sewage treatment and waterworks equipment in the United States have been in service without replacement for 20 years and longer—evidence of Everdur's ability to resist corrosion common to these operations. *Reg. U. S. Pat. Off.





Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment"—or for assistance of the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 56130

Everdur is Tough. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.



ANACONDA®

COPPER-SILICON ALLOYS

STRONG • WELDABLE
WORKABLE
CORROSION-RESISTANT

Sewage SLUDGE

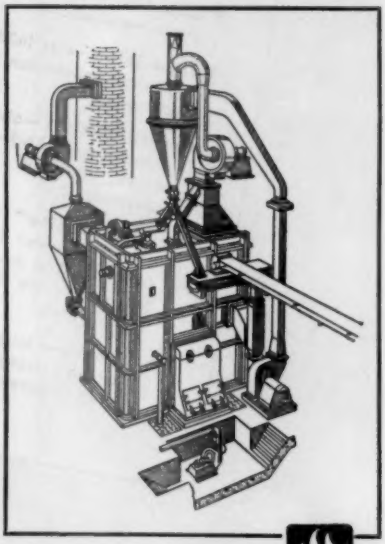
BURN IT!
SELL IT!

You can do both with the C-E Raymond System

For versatility alone, you can't beat the *C-E Raymond System of Flash Drying and Incineration!* With it, you can incinerate sewage sludge to a sterile ash . . . or flash-dry it to a fertilizer and soil conditioner that is readily marketed. Either operation can be performed alone, or combined in any proportion.

In either case, high-temperature deodorization of stack gases is available.

Whether you wish to incinerate or dry—look to the C-E Raymond System for the effective end to your sludge disposal problems. For specific recommendations for your community, get in touch with a C-E specialist at the office nearest you. He will be happy to work with you and your consultant.



COMBUSTION ENGINEERING

RAYMOND DIVISION

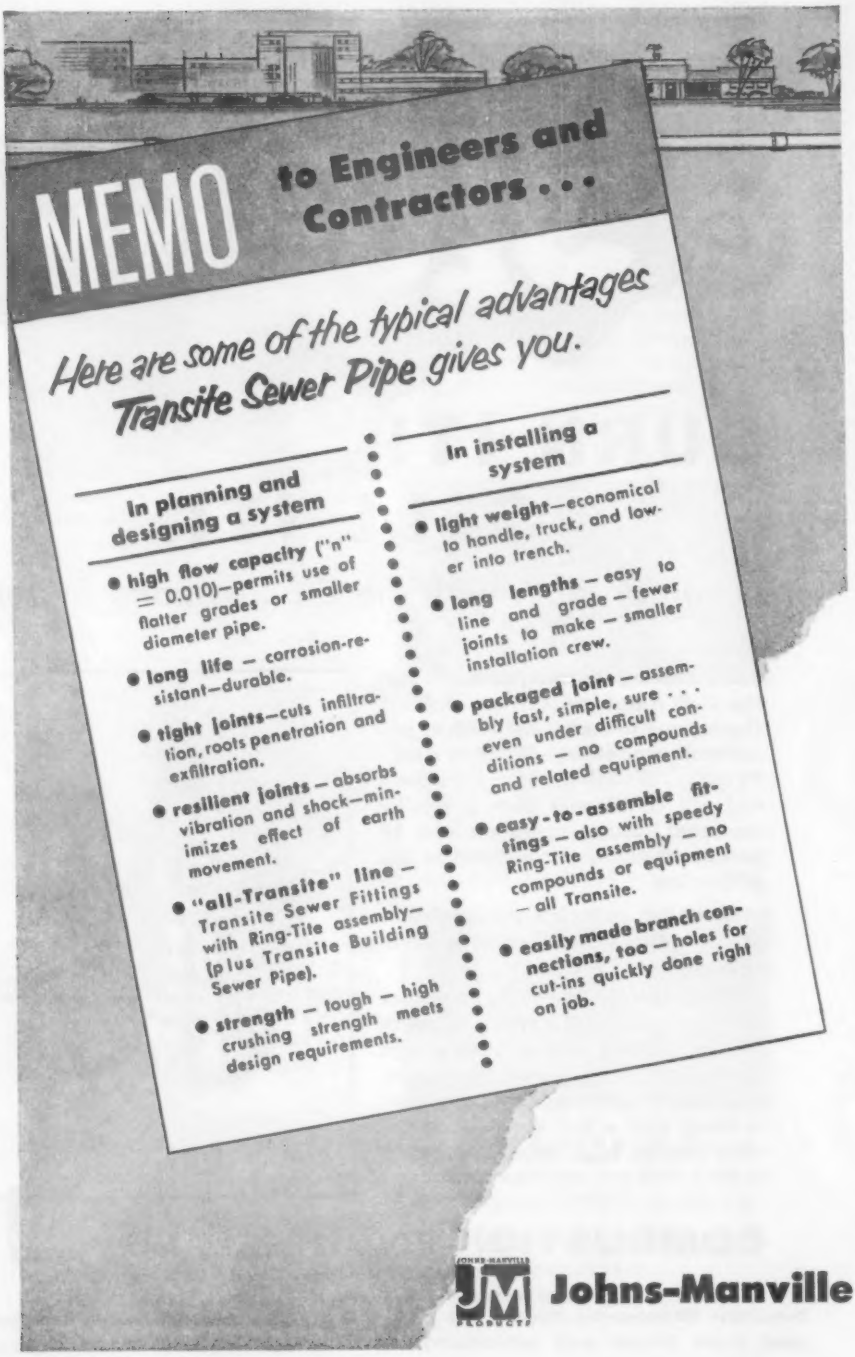
1315 North Branch Street, Chicago 22, Illinois

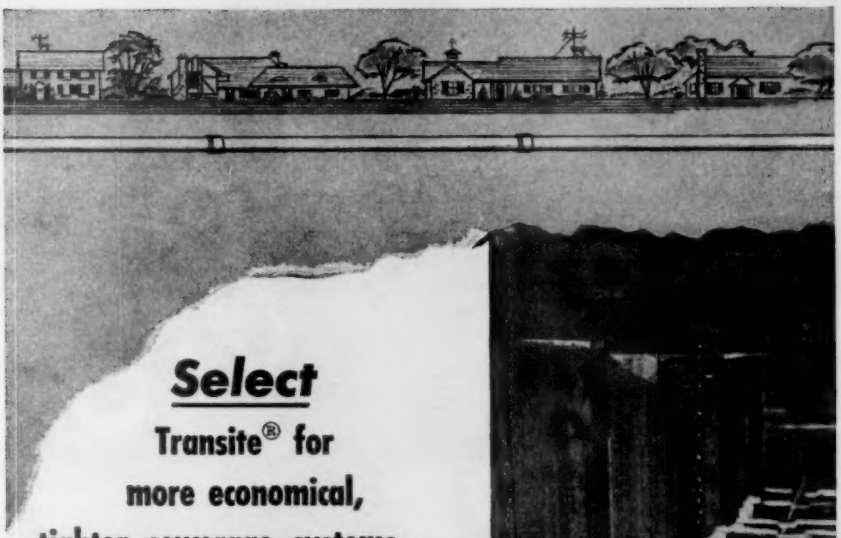
Eastern Office: 200 Madison Ave., New York 16, N. Y. *Western Office:* 510 W. Sixth St., Los Angeles 14, California

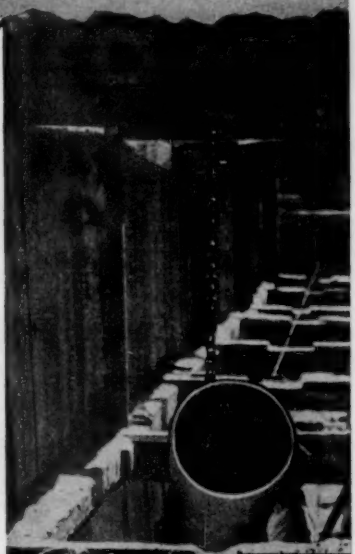
ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

C-E

B-930A


MEMO to Engineers and Contractors . . .
Here are some of the typical advantages Transite Sewer Pipe gives you.
In planning and designing a system
● high flow capacity ("n" = 0.010)—permits use of flatter grades or smaller diameter pipe.
● long life — corrosion-resistant—durable.
● tight joints—cuts infiltration, roots penetration and exfiltration.
● resilient joints — absorbs vibration and shock—minimizes effect of earth movement.
● "all-Transite" line — Transite Sewer Fittings with Ring-Tite assembly—(plus Transite Building Sewer Pipe).
● strength — tough — high crushing strength meets design requirements.
In installing a system
● light weight—economical to handle, truck, and lower into trench.
● long lengths — easy to line and grade — fewer joints to make — smaller installation crew.
● packaged joint — assembly fast, simple, sure . . . even under difficult conditions — no compounds and related equipment.
● easy-to-assemble fittings — also with speedy Ring-Tite assembly — no compounds or equipment — all Transite.
● easily made branch connections, too — holes for cut-ins quickly done right on job.
JM PRODUCTS
Johns-Manville





Select

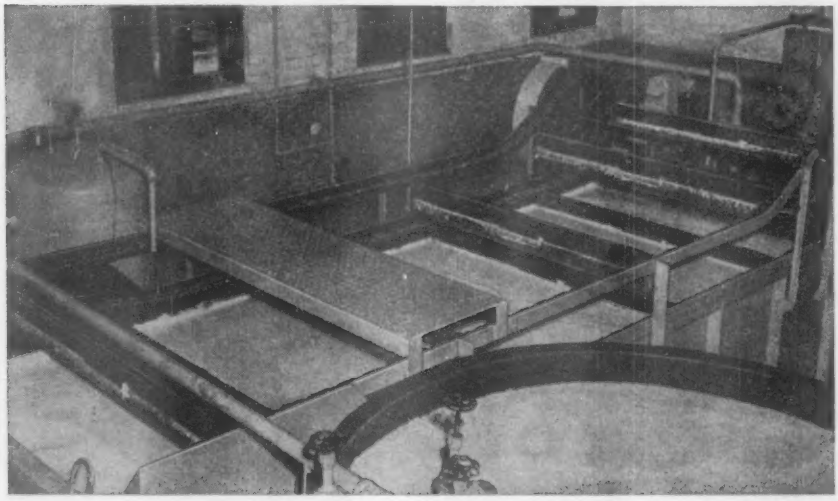
Transite® for more economical, tighter sewerage systems . . .

WHETHER a new sewerage system is being planned or additions to an existing one are being made . . . engineer and contractor alike will find a combination of qualities in performance-proved Transite Sewer Pipe that will fit their individual needs. They will find this holds true whether the local conditions call for (a) tight joints to protect against root growth and infiltration of ground water or (b) the strength and flow characteristics that mean definite savings in the design stage, during trenching and installation, and in operation as well.

For further information about Transite Sewer Pipe, write for Booklet TR-165A, Johns-Manville, Box 14, N. Y. 16, N. Y.

TRANSITE SEWER PIPE
with the RING-TITE® Coupling

FLOTATION IS *ONE* EASY WAY...



A typical example of Rex Float-Treat's ability to handle industrial waste. Valuable fats are recovered in this large gelatin plant.

To recover materials—eliminate pollution—clarify water for re-use

For industrial waste treatment...in oil refineries, tanneries, meat packing and food processing plants, chemical plants and many other places, Rex Float-Treat offers a proven way of recovering oils, fats, grease and other materials, clarifies process water and liquids for re-use, and reduces pollution.

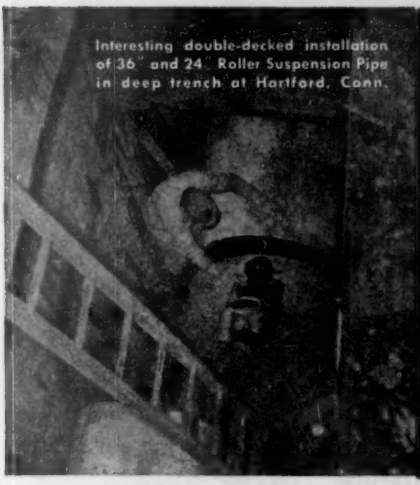
Rex Float-Treat eliminates the pumping of raw influent liquids so breakup of delicate, light solids...the emulsification of valuable fats and oils...is avoided. Because only recycle is pumped, operating costs are substantially reduced.

Float-Treat is available as a completely packaged unit in a metal tank or can be furnished for concrete tank installation.

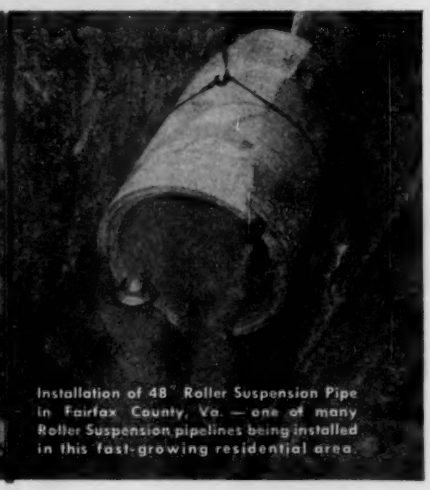
Rex Float-Treat is only one method of treating industrial and municipal wastes. Equipment is also available for screening, settling and grit removal. Get all the facts, today! Write CHAIN Belt Company, 4606 West Greenfield Ave., Milwaukee 1, Wisconsin.

CHAIN BELT COMPANY
MILWAUKEE 1, WISCONSIN

FOR EXCEPTIONAL STRENGTH
LOCK JOINT
ROLLER SUSPENSION PIPE



Interesting double-decked installation of 36" and 24" Roller Suspension Pipe in deep trench at Hartford, Conn.



Installation of 48" Roller Suspension Pipe in Fairfax County, Va. — one of many Roller Suspension pipelines being installed in this fast-growing residential area.

The unique manufacturing process by which Lock Joint Roller Suspension reinforced concrete sewer and culvert pipe is produced permits the use of a low water-cement ratio and a high proportion of stone in the mix. The concrete obtained by this system is unusually strong and resistant to abrasion.

Roller Suspension Pipe of equal wall thickness and steel area to cast or machine made concrete pipe consequently offers a considerable premium in strength and durability.

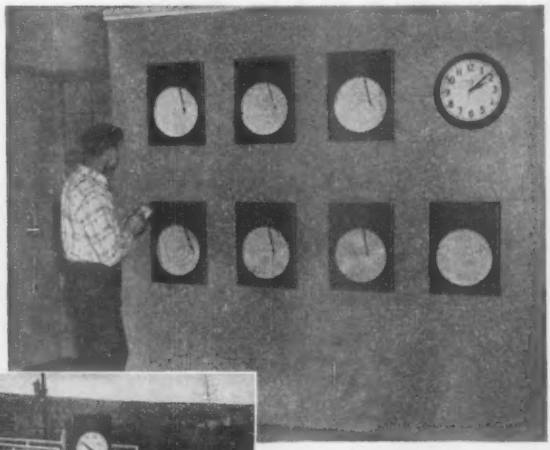
For projects requiring exceptionally rugged sewer or culvert pipe, specify Lock Joint's ultra-modern ROLLER SUSPENSION PIPE.

LOCK JOINT PIPE CO.
East Orange, N. J.

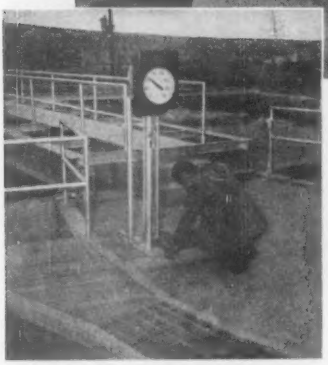
Sewer and Culvert Pipe Plants:

Kenilworth, New Jersey	Valley Park, Missouri	Cheyenne, Wyoming
Hartford, Connecticut	N. Kansas City, Missouri	Casper, Wyoming
New Haven, Connecticut	Tulsa, Oklahoma	Tucumcari, New Mexico
Beloit, Wisconsin	Oklahoma City, Oklahoma	Hato Rey, Puerto Rico
Chicago, Illinois	Wichita, Kansas	Ponce, Puerto Rico
Rock Island, Illinois	Denver, Colorado	Caracas, Venezuela

Also Great Lakes Concrete Pipe Company with plants at Buffalo, N. Y. and Henrietta, N. Y.



Brown indicating, recording, totalizing flow meters (top) for raw sewage and treated effluents, and (bottom) for air, return sludge flows and excess sludge. Raw incoming sewage is mixed with sponge-like, biologically-active sludge which absorbs pollution matter in the sewage. Sewage then flows to a clarifier, where sludge settles out, and clear, treated water overflows to the river. A portion of the settled sludge is reactivated in an aeration tank and is returned to the system to treat more sewage. Excess sludge is pumped to digesters.



Brown concentric-scale, indicating, float-actuated flow transmitter is used with a Parshall flume.

Brown Instruments chosen for new, cost-cutting Biosorption Process at Austin, Texas plant

THIS SEWAGE PLANT at Austin used to be a standard activated sludge operation. By converting to the new Infilco Biosorption Process, the plant increased its capacity 167%, saved $200,000 in initial costs.

As in a growing number of sewage plant installations, Brown instruments provide operators with accurate working information . . . assure efficient, economical operation.

Brown flow meters indicate, record and totalize flow rates of raw sewage influent, clarified effluents, air, sludge returned to the system, and excess sludge. Orifice plates are used with air flows, Venturi tubes with return and excess sludge flows, and Parshall flumes are used with raw sewage and clarified effluents.

For your own water or sewage treatment processes, there are Brown instruments to cover practically every measurement and control requirement. For a discussion of your particular project, call your local Honeywell sales engineer. He'll welcome the opportunity to talk things over with you and your consulting engineer . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

Brown Parshall flume indicators and air flow recorders are mounted outdoors near clarifiers and aeration tanks at the Biosorption sewage treatment plant in Austin, Texas.

MINNEAPOLIS **Honeywell**
BROWN INSTRUMENTS
First in Controls

Specify
IOWA
for every job
Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 28 **October, 1956** **Number 10**

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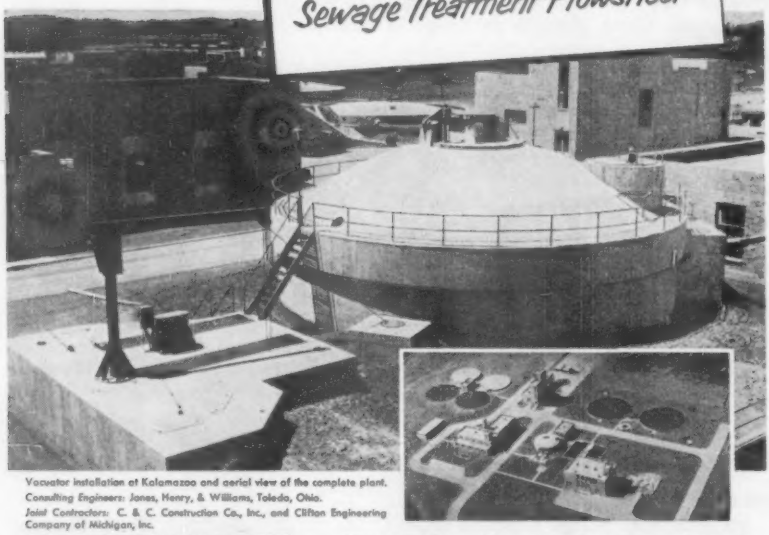

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Sewage Works

APPLYING RECENT RESEARCH TO DESIGN OF SEPARATE SLUDGE DIGESTERS

By Gordon E. Mau

Chief, Water Pollution Control Section, Kansas State Board of Health, Lawrence, Kans.

With the exceptions of volume requirements and the use of external heat exchangers, common practices in the design of sludge digesters have changed but little in the United States since the first separate digesters were constructed. Conventional designs provide digesters of relatively large diameter, shallow depth, and relatively flat bottom. This shape of digester, whether equipped with a floating or a fixed cover, results in only part of the total volume being available for digestion, because varying amounts of sludge accumulate on the bottom and scum develops on the surface.

An extreme example of this conventional design has been described in relatively recent literature and is shown in Figure 1. Included with Figure 1 are calculations indicating the volume available for active digestion under certain assumptions which allow for the accumulation of scum and varying amounts of inert sludge and grit.

Most regulatory agencies require 3 to 6 cu. ft. per capita of heated digester capacity for secondary treatment plants; 3 cu. ft. per capita is the usual requirement for a standard trickling filter plant, the most common method of secondary treatment. The same agencies commonly require 3.5 to 4 cu. ft. of digestion capacity in Imhoff tanks. Yet, approximately 55 days are required to digest sludge at 60° F. and approximately 23 days are required to digest sludge at 95° F. (1). Thus, only 17 to 33 per cent more volume is required for digestion in an Imhoff tank than is required in a separate heated digester, whereas at these temperatures the time for digestion in an Imhoff tank is about 240 per cent greater.

Part of the discrepancy in digestion requirements can be attributed to the fact that some of the volume in a separate digester must be available for supernatant, and some storage volume for digested sludge is usually needed regardless of the method of digestion. The question can then be asked: Is such a large increase in volume necessary solely to obtain a suitable supernatant?

In 1929 Goudey (2) reported that there were 59 separate sludge digestion plants, of which 41 were heated; three years earlier, on a trip to the eastern section of the United States, he found only three separate sludge digestion plants for small communities, none heated. He reported that 1.5 and 3.0 cu. ft. per capita were the common requirements for heated and unheated digesters, respectively.

Early research indicated that a volume of about 1 cu. ft. per capita was needed in a heated digester. This information was apparently the basis upon which state agencies established the earliest digester volume requirements. By the mid-1930's it was apparent that digesters were not performing up to expectations, so state

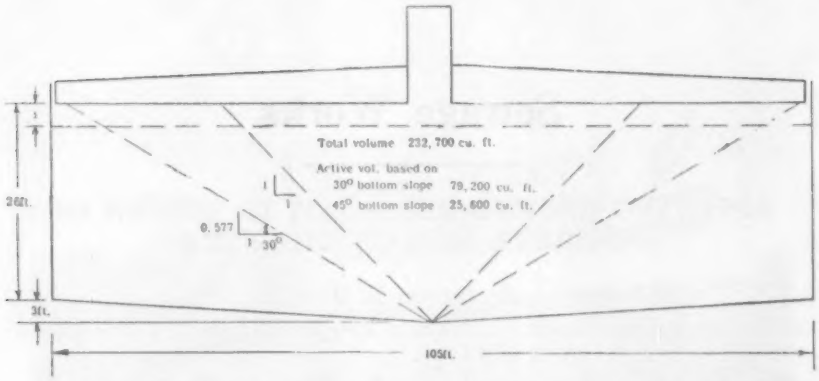

FIGURE 1.—An extreme example of common digester design in the United States.

agencies required more volume. Little attention was given to the shape of the structure other than how the shape might affect supernatant quality. However, relatively deep digesters with steeply hoppered bottoms (up to 1:1 being desirable) were considered necessary by some of the earlier workers (1).

In view of recent developments (3) (4)(5)(6) it appears that if current design practices are revised so that 100 per cent of a digester volume is used effectively, it will be possible to reduce total digestion volume requirements. This resolves itself into whether regulatory agencies revise their design policies, and require compliance, or whether designers make changes in the digester structure—a situation somewhat comparable to the old question of which comes first, the chicken or the egg.

Problems commonly associated with separate sludge digestion include scum, grit accumulations, supernatant containing digesting solids, and a rapid increase in the concentration of volatile acids. These problems tend to be intensified by the increased quantity of solids per capita brought about by the increasing use of home garbage disposals; the garbage load has also changed the sludge composition to some extent.

Changing from internal hot water coils to external heat exchangers as a means of heating has helped to control the scum formation in some cases, but has had little effect upon the accumulation of grit in digesters. The change usually results in a much poorer quality of supernatant with single-stage digesters.

Advantages associated with gas recirculation in digesters include an increased utilization of the digester volume, through elimination of scum and sludge accumulations, and a more uniform mixture of the digester contents. Some of the disadvantages experienced with gas recirculation include the need for extra equipment and, where only single-stage digestion can be practiced, a very poor quality supernatant—actually approaching the composition of the digesting mixture. However, through the use of gas recirculation, it has been possible to satisfactorily digest considerably larger concentrations of volatile solids per unit of total digester volume than had previously been possible in the same conventional digester. It is highly probable that much of the increased loading is possible because the inactive sections of the digester are minimized through the mixing action caused by the recirculated gas.

The following two examples support

the fact that the total volume of conventional digesters is not available for active digestion: The flat-bottomed, first-stage digester at Wellington, Kans., is 42 ft. in diameter, has a 21.7-ft. sidewater depth, and provides a total volume of 29,000 cu. ft. The unit was equipped with a scum stirrer and a sludge scraper mechanism until recently, when the plant was repaired and enlarged. For approximately one year sludge for heating was obtained from about two-thirds the depth at the side of the digester under the raw sludge inlet. It was decided to vary the operation to circulate sludge from the bottom and allow sludge to transfer to the second-stage digester from the two-thirds depth each time raw sludge was pumped. Within a few minutes after changing the method of circulation the temperature of the sludge from the digester dropped 10° F.

The first-stage digester at Junction City, Kans., is 43 ft. in diameter, has a 19-ft. sidewater depth with the bottom sloping 5.4 ft. to the center, and provides a total volume of 27,600 cu. ft. Sludge for circulation can be obtained from the bottom in the center, or from the side 13 ft. below the overflow level. For several months sludge for circulation was obtained from the side. After the volatile acids had been constantly below 100 p.p.m. for several weeks it was decided to circulate sludge from the bottom. After several hours the volatile acids increased to about 2,000 p.p.m.; circulation was then again obtained from the side and gradually the volatile acids decreased to the former level over a two-week period.

Because of the accumulation of inert sludge, grit and scum, it is doubtful that more than one-third to one-half of the total volume in many conventional digesters is effectively utilized. Through the use of gas recirculation, in digesters where this general assumption applies, it should be possible to increase the theoretical loading based on the total volume of the digester by up to three times while the actual organic loading per unit volume of actively digesting material remains the same.

A summary of the gas rates used with the various methods of gas recirculation is presented in Table I (3)(4)(5); in addition to the gas recirculation rate, an assumption has been made for the amount of gas normally produced by digestion at the reported loadings. These rates have then been added and transferred into an average rate per unit of liquid surface area in the digester. It will be noted from Table I that this rate varied from about 25 to 63 cu. ft. per square foot per day.

TABLE I.—Gas Recirculation in Sludge Digesters[1]

Location	Digester Diameter (ft.)	Gas Recirc. Rate (c.f.m.)	Assumed Gas Production[2] (c.f.m.)	Avg. Gas Rate at Dig. Surf. (cu.ft./sq.ft./day)[3]
Washington, D. C.	84	140[4]	103	63.3
		40[5]	103	37.2
Toronto, Ont.	100	80	54.6	24.7
Tulsa, Okla.	45	45	11.1	50.5
Columbus, Ohio	70	76	89.0[6]	61.8

[1] From data in Refs. (3)(4)(5).
[2] At 1 cu.ft per capita per day.
[3] Based on recirculated gas plus rate of gas production.
[4] Initially.
[5] Finally.
[6] Actual rate.

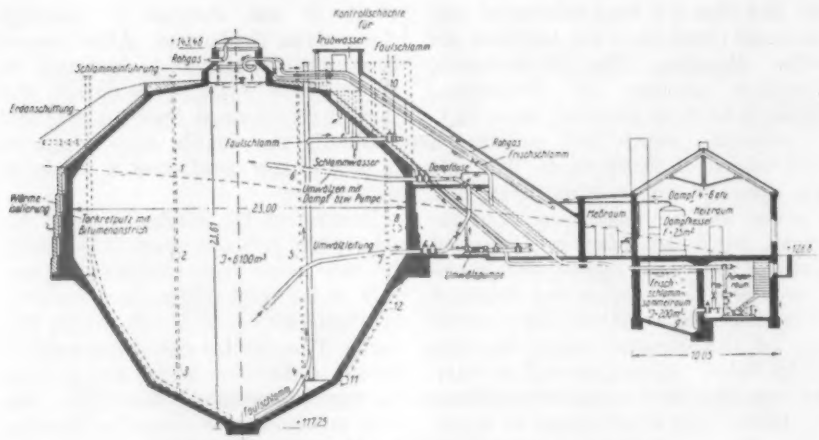

FIGURE 2.—Typical digester design in Germany.

Digester Capacity

The typical design of digesters in Germany differs considerably from that in the United States. A typical German design is presented in Figure 2. Such digesters have been designed in diameters and depths up to more than 30 meters. It is common to obtain gas production of about 1.0 cu. m. per day per cubic meter of digester volume. Assuming 1 cu. ft. of gas per population equivalent per day, this results in about 1 cu. ft. of digester volume being provided per capita, compared to 3 cu. ft. per capita in heated digesters in the United States. It should be noted that these typical German designs (7) and loadings are for relatively large plants.

Even with the relatively high digester loadings, the sludge digestion process is seldom interrupted in German plants. This is evident from the fact that many cars and trucks operate on sewage treatment plant digester gas; road maps are available indicating locations where such gas can be procured. Thus, continuous digestion must be assured in order to develop the market initially and in order to maintain a gas supply for the market.

The general shape of the German digesters causes the gas to leave the digesting sludge through a much smaller area at the liquid surface than is common with the same volume of digester in the United States. Time has proved that this shape minimizes the formation of scum and eliminates the accumulation of sludge and grit. The gas rate at the liquid surface of the digester shown in Figure 2 is calculated to be approximately 1,600 cu. ft. per square foot per day. This is a much greater rate than recent research has shown to

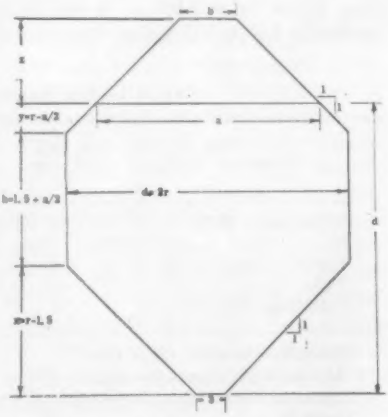

FIGURE 3.—Digester shape approximating a sphere.

be necessary for scum control (3)(4)(5)(6).

Assumptions

The preceding discussion poses the question: Can the principles of gas recirculation and the general shape of the German digester design be incorporated into one structure? By reference to Figure 3, it is apparent that this can be done if the following assumptions are made:

1. A cone-shaped top with a 1:1 slope.
2. A cone-shaped bottom with a 1:1 slope.
3. A 3-ft. diameter flat bottom.
4. A liquid depth from the bottom of the hopper to the overflow level equal to the maximum diameter, d.
5. A surface area with the diameter, a, such that with natural gas production (assumed to be 1 cu. ft. per capita per day) the gas will pass through the surface area at an average rate of 50 cu. ft. per square foot per day.
6. Two-stage digestion with 1.5 cu. ft. per capita in each stage of digestion. (The reason for this assumption is that it provides some safety factor over the unit volumes proposed by the most optimistic, while providing the storage volume for digested sludge needed in most plants to carry the plant through poor drying periods and times of difficulty. Also such volumes have been proved adequate for first-stage digestion in a number of plants; experience showing that at this volume at least 90 per cent and frequently up to 95 per cent of the total quantity of gas is produced in the first-stage digester.)

Calculations

Based on these assumptions, and employing the prismoidal formula in the following calculations, a mathematical expression is developed for the volume of each digester:

Sludge Volume Top Cone

$$= V_C = \frac{v}{6}\left[r^2\pi + 4\pi\left[\frac{r+\frac{a}{2}}{2}\right]^2 + \pi\left(\frac{a}{2}\right)^2\right]$$

$$= \pi/3[r^3 - (a/2)^3] \quad \ldots\ldots (1)$$

Volume Cylinder (mid-section)

$$= V_M = \pi r^2 h \quad \ldots (2)$$

Volume Bottom Hopper

$$= V_B = \frac{r}{6}[\pi r^2 + 4\pi(r/2)^2 + 0]$$

$$- \text{Volume in Bottom Tip of Cone}$$

$$= \frac{\pi r^3}{3} - \frac{\pi(1.5)^3}{3}$$

$$\approx \frac{\pi r^3}{3} \quad \ldots\ldots (3)$$

Total Sludge Volume

$$= V_I = V_C + V_M + V_B$$

$$= \frac{\pi}{3}\left[2r^3 + 3r^2h - \left(\frac{a}{2}\right)^3\right] \quad \ldots (4)$$

If over-all sludge depth $= d = 2r$ then

$$2r = h + r - 1.5 + r - (a/2)$$

and

$$h = 1.5 + (a/2) \quad \ldots\ldots (5)$$

Then

$$V_T = \frac{\pi}{3}\left[2r^3 + 3r^2\left(1.5 + \left(\frac{a}{2}\right)\right) - \left(\frac{a}{2}\right)^3\right]$$

$$= \frac{\pi}{3}\left[2r^3 + r^2\left(4.5 + \frac{3a}{2}\right) - \left(\frac{a}{2}\right)^3\right] \quad \ldots (6)$$

Substituting values for a and solving for r,

$$r^3 + \frac{r^2}{2}\left[4.5 + \frac{3a}{2}\right] = \frac{1}{2}\left[\frac{3V_T}{\pi} + \left(\frac{a}{2}\right)^3\right] \quad \ldots (7)$$

By substituting assumed values for a in Eq. 7, values for r may be obtained through trial and error procedures. The results are entered in Table II, along with the original assumptions, and the other dimensions have been calculated from the relationships indicated in Figure 3. The dimensions presented in Table II are presented graphically in Figure 4, which shows that all of the dimensions increase as the digester volume increases, with the exception of y, which changes but little except for the smallest digesters. The y dimension would not be of particular concern in digesters serving less than 15,000 to 20,000 population equivalent; it would certainly need to be given attention for digesters serving more than 50,000 population equivalent or else the head on the recirculation pumps would be quite high. By permitting a higher gas rate at the overflow level, which would not be detrimental, this dimension y would also increase; but in doing so diameter a would be reduced. Whether this should be done will depend upon the size of digester, the needed gas storage, the method of sludge dewatering and, in the case of sludge beds, the area of each bed.

Sludge Drying Beds

Of the foregoing conditions, probably the area of the individual sludge beds is the most important from the viewpoint of operation and safety. It is important to always have pressure inside of gas domes for digesters with fixed covers; with drying beds it should be possible to draw a bed of sludge without causing air to enter the digester. Assuming that the gas pressure inside the digester is equal to 8 in. of water initially, a quantity of sludge equal to the volume of gas storage in the unit could be withdrawn from the digester and this operation would only reduce the gas pressure

TABLE II.—Dimensions of Digesters for Various Populations, Based on Figure 3 and the Listed Assumptions

Gas[1] (cu.ft./day)	Surface Area[2] at Liquid Level (sq.ft.)	Diameter, a, at Liquid Level (ft.)	Volume in First-Stage Digester[3] (cu.ft.)	Diameter, d (ft.)	Sidewall Height, h (ft.)	Depth, x, of Bottom Hopper (ft.)	Elev. of Liquid, y, above Sidewall (ft.)	Top Diameter, b (ft.)	Cone Top Height, z, above Liquid[4] (ft.)
2,000	40	7.13	3,000	18.6	5.1	7.8	5.7	5[5]	1.1
5,000	100	11.3	7,500	25.1	7.15	11.0	6.9	5[5]	3.15
10,000	200	15.9	15,000	31.4	9.45	14.2	7.7	5	5.35
15,000	300	19.5	22,500	35.9	11.25	16.5	8.2	5	7.25
20,000	400	22.5	30,000	39.4	12.75	18.2	8.5	5	8.75
25,000	500	25.2	37,500	42.2	14.1	19.6	8.5	5	10.1
30,000	600	27.6	45,000	44.8	15.3	20.9	8.6	5	11.3
40,000	800	31.8	60,000	49.2	17.4	23.1	8.7	5	13.4
50,000	1,000	35.6	75,000	—	—	—	—	5	—
60,000	1,200	39.2	90,000	56.0	21.1	26.5	8.4	5	17.1
70,000	1,400	42.3	105,000	—	—	—	—	5	—
80,000	1,600	45.2	120,000	61.8	24.1	29.2	8.1	5	20.3
90,000	1,800	48.0	135,000	—	—	—	—	5	—
100,000	2,000	50.4	150,000	66.0	26.7	31.5	7.8	5	22.7

[1] Based on 1 cu.ft. per capita per day in a trickling filter plant.

[2] Based on a gas rate of 50 cu.ft. per square foot per day from natural digestion at a rate of 1 cu.ft. per capita per day.

[3] Based on 1.5 cu.ft. per capita.

[4] Assuming top diameter, b, equal to 5 ft.

[5] Must provide vertical gas dome above cone to maintain a minimum of 5 ft. between liquid level and top of gas dome.

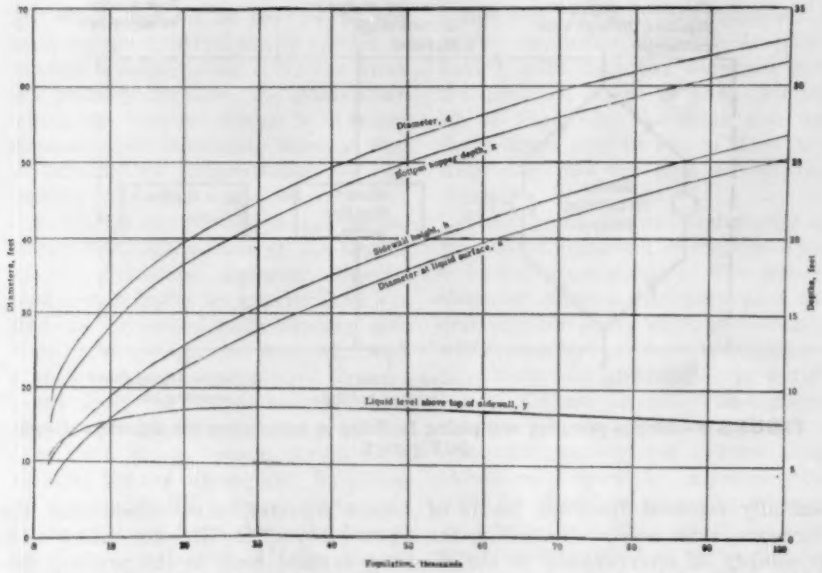

FIGURE 4.—Relationship of dimensions for two-stage digesters based on 1.5 cu. ft. per capita volume in each. (Values from Table II.)

to approximately 4 in. of water. Thus, for the most effective utilization of fixed cover digesters, each individual drying bed (where sludge beds are used) should be relatively small. The rather frequent withdrawal of one small bed of sludge, as outlined, has the advantage that continuous-flow principles of digestion can be approached, if the beds are utilized properly, and also it is unnecessary that water be pumped into the digester when sludge is withdrawn to a bed.

Two-Stage Digestion

An arrangement for two-stage digester design, based on the foregoing information, is shown in Figure 5. This proposal also illustrates a method by means of which pipes can be es-

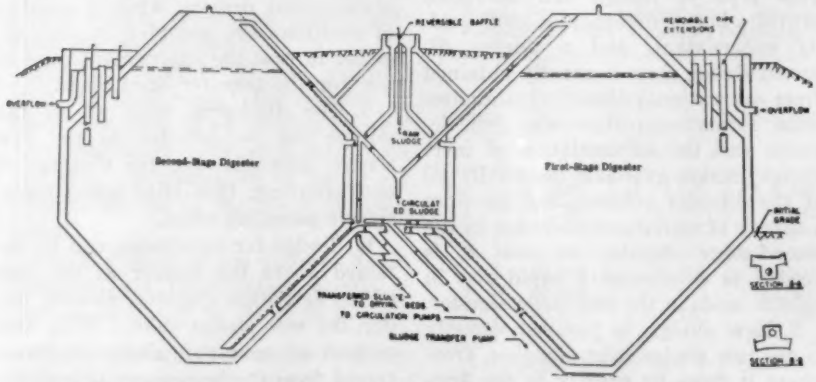

FIGURE 5.—Recommended design of two-stage digesters and sludge piping.

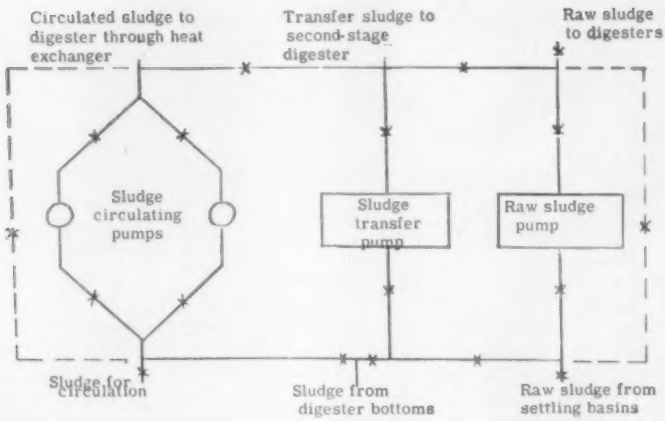
Circulated sludge to digester through heat exchanger
Transfer sludge to second-stage digester
Raw sludge to digesters
Sludge circulating pumps
Sludge transfer pump
Raw sludge pump
Sludge for circulation
Sludge from digester bottoms
Raw sludge from settling basins

FIGURE 6.—Sludge pumping and piping facilities to accompany the digesters shown in Figure 5.

sentially removed from the inside of digesters, thus nearly eliminating the possibility of interruptions to the digestion process due to pipe breakage and failure of pipe supports.

To facilitate operation of the digesters shown in Figure 5, pumping and piping arrangements, located in a separate control building, are shown in Figure 6. The facilities illustrated in Figures 5 and 6 offer the following advantages:

1. Two-stage digestion can be practiced, heating only the first-stage digester and obtaining all the supernatant from the second-stage unit. This type of design and operation provides better digestion, a good quality supernatant, and a thicker digested sludge than is usually obtained from conventional digesters; minimizes scum formations; eliminates grit deposits and the accumulation of inert sludge; makes available essentially all of the digester volume; and provides a supply of well-digested sludge in the second-stage digester in case it is needed to counteract a rapid rise in volatile acids in the first-stage digester.

2. Raw sludge is pumped directly to the raw sludge inlet chamber, from where it flows by gravity to the first-stage digester, thus eliminating the possibility of the digester contents being drained back to the primary settling basins when check valves fail to close.

3. No extra equipment, over that needed for the normal pumping and heating of sludge, is necessary in order to obtain an adequate gas rate at the sludge surface which minimizes, and probably eliminates, scum formations.

4. The depth from which supernatant is obtained is selected by manually changing the removable pipe extensions at the top of the supernatant pipes. Thus a number of valves and sampling pipes are eliminated from conventional designs, while a number of overflows are provided in each digester in case the supernatant pipe in use (or the transfer line) clogs.

5. The discharge from all of the pumps can be diverted to the raw sludge inlet chamber for observation and sampling, thus eliminating undesirable sampling cocks.

6. Sludge for circulation can be obtained above the hopper at the side of the first-stage digester, directly under the raw sludge inlet. With this method of operation sludge is transferred from the bottom and side of the

first-stage digester to the top of the second-stage unit frequently enough to prevent a supernatant overflow from the primary digester; the point from which the transfer sludge is obtained depends upon laboratory tests, so that a satisfactory concentration of digesting solids is maintained.

7. Sludge for circulation can be obtained from the bottom of the hopper in the first-stage digester, allowing sludge to transfer by gravity from the first- to the second-stage digester each time raw sludge is pumped, such transfers being accomplished from a point above the hopper and 90° from the raw sludge inlet.

8. Each sludge pump serves as a standby for the others; also, by means of the centrifugal pumps, sludge can be recirculated from above the hopper or from the bottom of the hopper while using either of the two piston pumps for raw sludge.

9. All the pumps can be operated simultaneously for their primary purpose.

10. The direction of flow through the sludge drawoff pipes can be reversed for the sections adjacent to and in the digesters. By providing the piping shown by dashed lines in Figure 6, the flow can be reversed through all of the suction pipes.

11. Each digester can be used independently of the other but, with the piping shown, the stages cannot conveniently be reversed.

12. The junction of the sidewall with the fixed cover (the location at which gas leaks often develop in common fixed cover designs) is submerged and thus the possibility of losing gas through cracks in the cover is minimized.

13. The shape of the digester would facilitate gas recirculation should it ever be necessary to resort to it.

The preceding approach to digester design is primarily applicable to plants requiring only two digesters. It is also applicable, however, to plants having more than two digesters, with the possible exception that, keeping all of the units the same size and shape, there may be two to three first-stage digesters for each second-stage digester.

The type of digester and piping arrangement suggested in Figures 5 and 6 is not experimental. The general shape of digester has been used successfully for many years in Germany, while similar piping arrangements have been used successfully in a number of Kansas plants. The digesters in one Kansas plant, completed in June 1955, are of the general shape shown in Figure 5. Another plant with the digesters generally arranged as proposed in this article is under construction; the bid prices for this project are presented in Table III.

Recent trends in digester designs in Kansas are indicated in Table IV.

Of the 13 two-stage digestion plants completed from 1953 to 1955, three have 1:1 hopper bottoms; of the 13 under construction January 1, 1956, 9 have 1:1 hopper bottoms. In some cases both digesters have fixed covers, in other cases the first-stage digester has a fixed cover and the second-stage digester has a floating cover, and in

TABLE III.—Comparison of Bids for Howard, Kans., Sewage Treatment Plant: Design Population 1,700; Unheated Digesters

Bidder	Single Digester; 1 Sludge Pump	Two-Stage Digester;[1] 3 Sludge Pumps; Larger Building and Control House	Difference
1	$70,540	$ 76,628	$ 6,088
2	74,700	83,600	8,900
3	83,965	101,255	17,290
4	83,970	94,470	10,500
5	88,500	97,000	8,500
6	89,980	103,980	14,000
7	95,890	107,110	11,220

[1] 1:1 hopper bottom and 1:1 cone-shaped top.

TABLE IV.—Number of Single-Stage and Two-Stage Digester Plants Completed or Under Contract in Kansas from January 1, 1953 to January 1, 1956

Period	Number of Single-Stage Digester Plants	Number of Two-Stage Digester Plants
1953–55, incl.	5	13
Under construction, January 1, 1956	3[1]	13

[1] Two in rapidly growing areas; expansion indicated before current project is completed.

one case both digesters have floating covers. The fixed covers include flat, arched domes and conical covers with slopes of the latter varying from one vertical to two horizontal up to one vertical to one horizontal.

The contract prices of recent new plants (cost of expanded plants not included) in Kansas are shown in Figures 7 and 8. These charts should not be interpreted as indicating that two-stage digestion, with or without a 1:1 hopper bottom in the digester and a 1:1 cone top, is less costly than a single digester. However, they do indicate the plants designed with two digesters are not unduly expensive and that any slight additional cost is more than balanced by the provision for two-stage digestion.

The advantages of two-stage digestion over single-stage digestion by far outweigh any slight additional cost. By far the greatest difficulty with separate sludge digestion in Kansas has been due to single-stage digesters, including those plants with more than one digester but in which the piping is so arranged that only single-stage digestion can be practiced. Experience has proved that the advantages are so great that the tentative revised sewerage design policy in Kansas calls for two-stage digesters with 1:1 hoppered bottoms, unless there is some special reason for waiving the requirement. It is obvious from Table IV and the

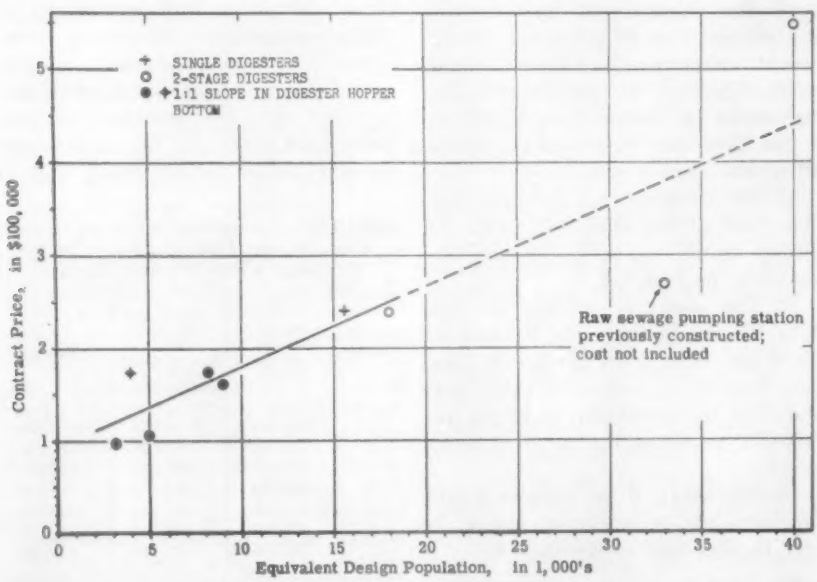

FIGURE 7.—Contract price of new separate sludge digestion primary sewage treatment plants in operation or under contract in Kansas from January, 1953 to April 20, 1956.

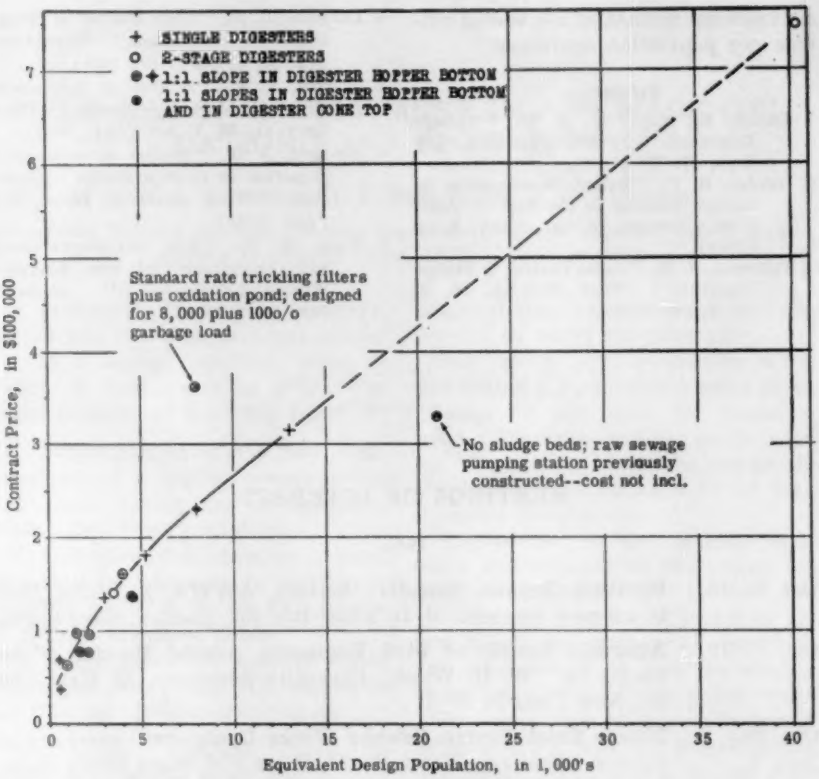

FIGURE 8.—Contract price of new separate sludge digestion secondary sewage treatment plants placed in operation or under contract in Kansas from January 1, 1953 to April 20, 1956.

subsequent discussion that most of the consulting engineers have already adopted this type of design.

Summary and Conclusions

1. A method has been presented whereby the results of modern research can be applied to the design of separate digesters, so that essentially all of the volume will be available for digestion and so that operating problems will be minimized.

2. Cost data have been presented which indicate that the method of design advanced does not materially affect costs.

3. Plants already constructed on these principles show that the suggested method of design is practical.

4. The method of design advocated is a means whereby it will probaby be possible to reduce digester volume requirements, especially in larger plants equipped with vacuum filters for dewatering digested sludge.

5. When structures are designed for 100 per cent utilization of the volume for digestion in first-stage digesters, it will be much easier for designers to begin basing designs upon weight of volatile solids added per day per unit of digester volume, rather than on the

conventional method of a specified volume per population equivalent.

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MEETINGS OF INTEREST

1956

Oct. 15–16	**Maritime Branch, Canadian Section, AWWA,** St. John, New Brunswick, Canada. J. D. Kline, Box 608, Halifax, Nova Scotia.
Oct. 15–19	**American Society of Civil Engineers,** Annual Meeting, Pittsburgh, Pa. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.
Oct. 29–Nov. 2	**Illinois Short Course, Sewage Works Operators,** University of Illinois. Sanitary Water Board, Room 616, State Office Building, Springfield, Ill.
Nov. 12–16	**American Public Health Association,** 84th Annual Meeting, Atlantic City, N. J. Executive Secretary, 1790 Broadway, New York 19, N. Y.
Nov. 12–17	**Public Works and Municipal Services Congress and Exhibition,** Olympia, London, England. The Municipal Agency Ltd., 70 Victoria St., London, S. W. 1, England.
Nov. 13	**Conference of Federal Sanitary Engineers,** Pan-American Room, Hotel Statler, Washington, D. C. (2 PM)
Nov. 19–20	**Sanitary Engineering Conference,** Kansas City Section, American Society of Civil Engineers, Continental Hotel, Kansas City, Mo. R. G. Kincaid, Chairman, P. O. Box 7088, Kansas City, Mo.
Nov. 27–30	**National Chemical Exposition,** Public Auditorium, Cleveland, Ohio. American Chemical Society, 1155 16th St., N. W., Washington, D. C.

1957

Mar. 11–15	**International Atomic Exposition,** Philadelphia, Pa.

FIELD USE OF RADIOTRACER IN A SEWAGE OXIDATION POND FLOW STUDY

By E. C. Tsivoglou, D. A. Pecsok, and R. F. Valentine

Respectively, Sanitary Engineer, Sanitary Engineer, and Health Physicist, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

A radioactive tracer field investigation of flow characteristics was carried out at a sewage oxidation pond at Philip, S. Dak., early in 1955. The major purposes of this study included:

1. Determination of the flow characteristics of a typical sewage oxidation pond having no outlet, under winter (ice cover) conditions;
2. Collection of information to serve as a basis for planning the location of sampling points in future field studies of sewage oxidation ponds;
3. Development of suitable techniques and experience with regard to the field use of radioactive tracers.

The sewage oxidation lagoon at Philip is relatively small and shallow with a center inlet and no outlet, and is the only means of sewage disposal for this town of 700 persons. The quantity of radioisotope required for the study was, therefore, relatively small. Also it was probable that this lagoon would still have its ice cover by the time the field study could be commenced (early March 1955).

Figure 1 depicts the general shape of the lagoon and its dimensions as well as the location of the sewage inlet. The lagoon area is approximately 1.5 acres, and the average depth of liquid was about 2 ft. at the time of the field study. Although there was no outlet from the pond at the time of this study, eventually the lagoon content will overflow to a second cell immediately adjoining it and separated from it by a dike. It is anticipated that the second cell will not require an outlet for some time.

Raw sewage flows by gravity to the wet well of a pumphouse located about one-quarter mile from the oxidation pond. Duplicate pumps, which operate alternately, pump the sewage to the lagoon through 1,040 ft. of 6-in. diameter force main.

Radioiodine (as NaI in basic solution) was selected as the tracer for use in the field study. Its half life (8 days) is of sufficient length to accommodate the purposes of the study, yet short enough so that the amount remaining in the lagoon a few weeks after completion of the study would be small. Its behavior characteristics are fairly well defined by its wide use in other experiments. There was some question as to whether an important fraction of the radiotracer might be adsorbed on sewage and other suspended solids and settle rapidly to the bottom of the pond. It was decided that the addition of sufficient "carrier" (potassium iodide) would probably reduce this effect to a negligible level.

On the morning of the initial dosing a preliminary inspection of the lagoon indicated that about 12 per cent of the lagoon area was open water surrounding the inlet (Figure 1). The remainder was ice-covered, but parts of the cover were quite thin. This condition was the result of several days of thawing temperatures immediately preceding the study. At the time of the inspection the wind velocity was about 23 m.p.h. from the northwest.

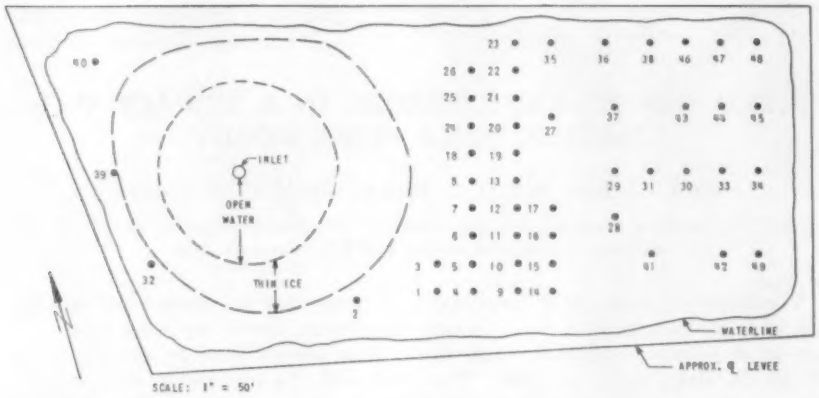

FIGURE 1.—Location of sampling holes in ice-covered lagoon.

In order to obtain a continuous record of sewage flow from Philip during the period of the experiment, personnel of the South Dakota State Health Department installed and operated a float-type water level recorder at the wet well of the pumphouse. This flow record was kept for a period of one week, starting on the date of dosing.

Weather information during the study was obtained at the Philip Airport.

Test Procedures

Dosing

Several alternatives were considered in connection with introducing the radiotracer into the lagoon. Adding the radioiodine to the contents of the wet well at the pumphouse appeared to be the least difficult method for dosing, but the dilution which would occur before the iodine reached the lagoon was undesirable. Dosing at the inlet to the lagoon was rejected because of access difficulties and the possibility of departure from the normal inlet flow pattern.

The dosing arrangement finally used involved introduction of a concentrated dose at the suction side of one of the pumps in the pumphouse. In this way it was possible to introduce the iodine in a single concentrated dose without interfering in any way with normal operation at the pumphouse. Good control was retained during the dosing operation.

The dosing procedure was as follows:

A standpipe was installed on the suction side of the pump; the solution of radiotracer was poured into this standpipe while the pump was shut off; a few seconds after the pump began operating, a valve at the base of the standpipe was opened, permitting the iodine solution to be drawn into the pump suction. As the standpipe emptied, water was poured in to wash out any remaining traces of iodine. The normal pumping cycle was such that the pump would operate for about 1½ min.; this period was extended slightly by manual control to ensure sufficient time for the entire dosing operation. The gate valve on the standpipe was then closed and the pump stopped. The dosing arrangement was tested with water before the radioiodine was used.

The primary solution of I^{131} was shipped from Oak Ridge, Tenn., directly to the offices of the South Dakota State Health Department at Pierre, S. Dak., and was transported from there to Philip. The shipment

contained 500 millicuries (mc.) of I^{131} at the time it left Oak Ridge (8:00 AM, March 8, 1955) as NaI in 7.7 ml. of basic Na_2SO_3 solution. In the mobile laboratory at Philip this primary solution was diluted and counted. One gram of potassium iodide was added to serve as a "carrier" to prevent excessive adsorption of the radioiodine by sewage solids. Allowing for decay of the original shipment, about 380 mc. were used in a single dose. Personnel who carried out the dosing operation were equipped with pocket dosimeters to measure the radiation dose received. As anticipated, this dose was insignificant. After introduction of the I^{131} was completed the piping in the dry well was examined for residual radioactivity by use of a radiation survey instrument. There was no evidence of significant contamination.

Instrumentation

Two laboratory counters with end-window Geiger tube probes were used to monitor the radiotracer and the equipment. During the study a number of lagoon samples were collected in 300 ml. bottles, for comparison with the field counts, and assayed in the mobile laboratory. The procedure consisted of evaporating a portion in an aluminum planchet after the addition of potassium iodide and alkalinity, and then counting with the laboratory instrument. Several of these samples were also filtered before the assay, in order to estimate the fraction of radioactivity bound up with suspended solids.

Two portable field scalers with Geiger tube probes were used in the field study. The probes were waterproofed with long rubber balloons, so that they could be submerged in water for the purpose of making direct water counts through holes in the lagoon ice-cover. These instruments were calibrated against known concentrations of I^{131} in water and tested for satisfactory operation at low temperatures before shipment to South Dakota.

The field survey procedure involved taking two direct counts at each ice hole, the first with the Geiger tube immersed to a level just under the ice layer, and the second with the detector lowered to the lagoon bottom. A number of air and water background counts were made during the study, and the rubber balloon protective cover was changed several times.

Field and Laboratory Results

The prevailing wind direction during the several hours following dosing was from the northwest, or in a path from the lagoon inlet toward ice holes Nos. 11 and 12. The average wind velocity increased from about 20 m.p.h. at the time the radioiodine reached the lagoon to 40 m.p.h. two hours later with gusts up to 50 m.p.h.

Sewage flows computed from the record made at the pumphouse wet well are indicated in Table I.

The per capita daily sewage flow rate on March 11, 1955 and during an

TABLE I.—Sewage Flows During Study

Date	Time	Sewage Flow		
		(g.p.m.)	(g.c.d.)[1]	(gal.)
Mar. 11	10:43 AM–12:45 PM	47.5	98	5,800
Mar. 11	10:43 AM–3:40 PM	48.2	100	14,300
Mar. 11–12	10:43 AM–8:56 AM	37.2	76	49,600
Mar. 11–12	10:43 AM–11:50 AM	39.0	80	58,800

[1] Gallons per capita per day.

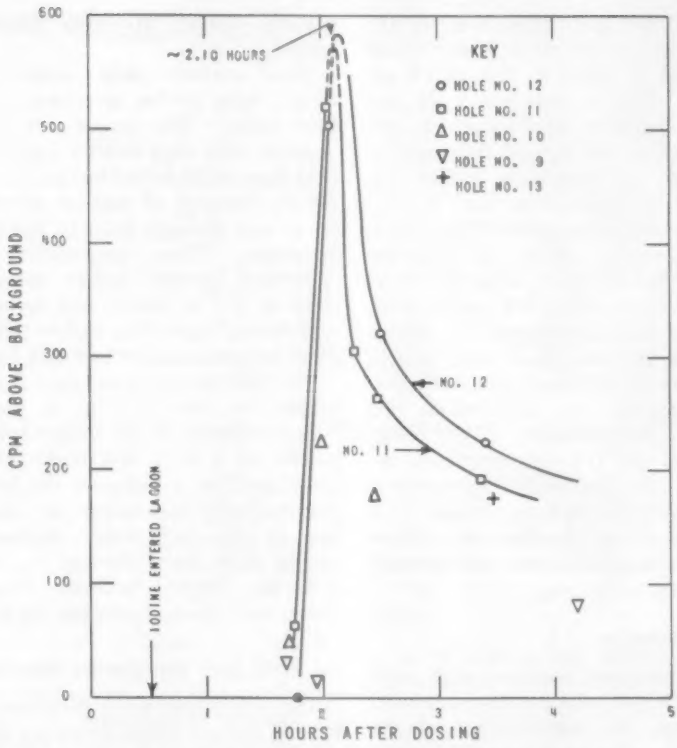

FIGURE 2.—Radiation count rate above background radiation immediately after dosing.

ensuing 25-hr. period probably reflects the preceding several days of thawing weather. Per capita daily flow rates six days later were lower, namely, 50 gal. per capita per day over a 24-hr. period, with an early morning high of 70 gal. and a low of 26 gal. during the pre-dawn hours.

Calculations based on the known sewage flow rate on March 11 and the volume of the force main indicated that the radioiodine entered the lagoon 32 min. after it was introduced at the pumphouse, or at 11:15 AM.

Figures 2, 3, and 4 indicate the observed patterns of consecutive field counts made on March 11 and 12 just under the ice layer, at selected locations downwind from the inlet. Unfortunately, the early failure of one of the two field scalers, the poor condition of the ice on the lagoon, and the rapidity with which the radiotracer was carried, made it impossible to obtain sufficient similar data at ice holes upwind from the lagoon inlet during the first few hours after dosing.

Figure 2 shows the count rates above the background radiation at ice holes Nos. 9, 10, 11, 12, and 13 as observed during the hours immediately after dosing. The radioiodine reached a peak concentration at these holes about 2.1 hr. after dosing, or 1.6 hr. after the iodine entered the lagoon. This set of ice holes was about 160 ft. away from the lagoon inlet.

Count rates observed at holes Nos. 5, 6, 7, and 8 during the first several hours after dosing are given in Figure

3. This set of holes was about 135 ft. removed from the lagoon inlet. The data are not as plentiful as desired due to circumstances previously outlined, but are sufficient to indicate that the radioiodine concentration reached a peak at this location about 1.7 hr. after dosing at the pumphouse and 1.2 hr. after entering the lagoon. Hole No. 5 is at a somewhat shallower point of the lagoon than the others, and data for this point have been plotted separately. Figure 4 presents the same information during a period of 24 hr. following dosing.

The radioiodine reached a peak concentration at 135 and 160 ft. away from the lagoon inlet much sooner than could be expected on the basis of the sewage flow rate and volume displacement computations. In this regard it is pointed out that the two locations involved lay directly in the path of the oncoming wind, and that during the 2 hr. following dosing the average wind velocity varied between 20 m.p.h. and 40 m.p.h., with gusts reaching 50 m.p.h.

All of the available evidence indicates that the radioiodine traveled out from the lagoon inlet in a thin stratified layer during the first hours after it left the force main. Early field counts at ice holes Nos. 1 through 8, about 1.4 hr. after dosing, were four times as high just below the ice layer as they were near the lagoon bottom, indicating a definite stratification. Similar pairs of field counts 24 hr. after dosing (March 12) showed no

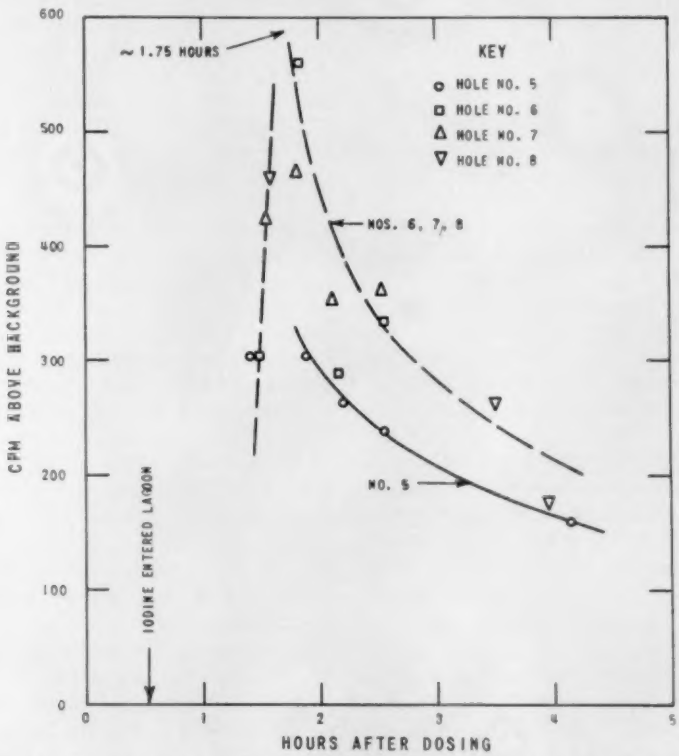

FIGURE 3.—Radiation count rate during the first several hours after dosing.

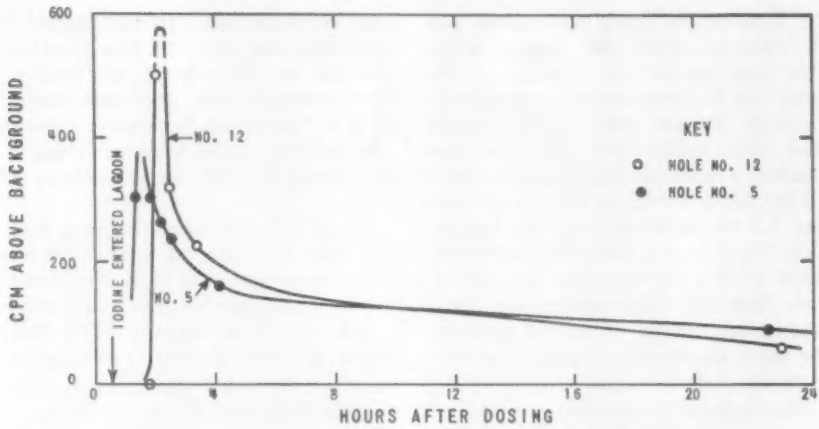

FIGURE 4.—Radiation count rate during the 24-hr. period following dosing.

such effect, and indicated no significant difference between top and bottom count rates.

Calculations based on the known sewage flow and lagoon volumes further demonstrate the stratification of radioiodine during the early period after dosing. During the period from 10:43 AM to 12:50 PM on March 11, the sewage flow rate into the lagoon was about 47.5 g.p.m. (Table I). The total lagoon volume to the west of ice hole No. 12 (assuming no directional wind effect on the radioiodine flow) was about 500,000 gal. At the prevailing sewage flow rate it would take about seven days for the iodine to reach hole No. 12 on the basis of volume displacement. Figure 2 indicates that the I^{131} reached hole No. 12 about 1.6 hr. after it entered the lagoon.

A more realistic approach might be to assume that the inflowing sewage (and I^{131}) traveled mainly in a direction toward hole No. 12 because of the wind effect during the critical period of time. In other terms, it might be supposed that the sewage did spread out in a fanlike or triangular pattern from the inlet toward hole No. 12. On this basis a much smaller lagoon volume is involved; at the very least, however, it is 85,000 gal. Volume displacement calculations then indicate that at least 1.2 days are required for the I^{131} to reach hole No. 12. This time is still much greater than the observed 1.6 hr. Accordingly, it is concluded that as a result of the combined effects of wind and the warmer temperature of the incoming fresh sewage, marked stratification of the fresh sewage occurred during at least the first 2 hr. after the sewage reached the lagoon.

Field and laboratory data for March 12, approximately 24 hr. after dosing, indicate quite a different picture. Field radioactivity measurements were made at 32 different ice holes selected to be representative of the entire lagoon. Water samples for laboratory radioassay were taken at 16 of these locations. Both laboratory and field determinations showed widespread general dispersion of the I^{131} throughout the lagoon volume, except for one minor area at the southeast corner of the lagoon where field counts were slightly lower. There was no significant difference at any location between field count rates immediately under the ice layer and near the lagoon bottom.

TABLE II.—Radioactivity of Filtered versus Unfiltered Samples

Ice Hole No.	Counts Per Minute Above Background Radiation		
	Unfiltered	Filtered	Per Cent
17	550	540	98
19	590	440	75
34	630	580	92
36	750	790	105

Laboratory determinations on 16 samples collected from the lagoon on March 12 at widely scattered locations indicated a concentration of I^{131} between 65 and 125 $\mu\mu$c. per milliliter. The average result was 99 $\mu\mu$c. per milliliter. The total volume of the lagoon is estimated at 3.11×10^9 ml. On this basis, the total radioiodine content 24 hr. after dosing was within the range 200 to 390 mc., the average being 310 mc. This amount of radioactivity is in close agreement with the 350 mc. expected on the basis of the 4.1 day old shipment of 500 mc.

Portions of four of the 16 laboratory samples collected on March 12 were filtered through coarse paper and count rates of the filtrate were made for comparison with unfiltered sample determinations in order to obtain a rough estimate of the extent of adsorption of the I^{131} by suspended solids. Table II indicates the results of this analysis.

These data indicate that the radioiodine used in this study was not significantly adsorbed by the suspended solids present. For the same chemical form of I^{131}, used without a "carrier," the work of Steel and Gloyna (1) indicates that "algae and associated material" did not adsorb or take up an important fraction of the radioiodine under their test conditions.

Summary and Conclusions

A single concentrated dose of 380 mc. of I^{131} was introduced into the sewage oxidation pond at Philip, S. Dak., to serve as a radiotracer to facilitate observation of the flow characteristics of such a pond under winter conditions. The following conclusions may be drawn from the field study:

1. Even though about 90 per cent of the lagoon was covered by a sheet of ice, the combined factors of wind speed and fresh sewage-lagoon temperature differential had a significant effect on the distribution of inflowing sewage. Stratification of the fresh sewage occurred over a large area of the lagoon, as indicated by the movement of the radiotracer. The fresh sewage, being warmer than the lagoon contents, stayed at the water surface for a sufficient period of time, so that the wind affected its distribution.

2. The radiotracer mixed with the pond contents much more rapidly than would be anticipated on the basis of volume displacement calculations. This rapidity of mixing, even under a nearly complete ice cover, indicates that interpretation of chemical analyses on the basis of calculated retention periods may lead to gross error. This effect might be more pronounced during the warmer part of the year. On the other hand, it appears that an adequate chemical description of pond contents can probably be obtained by analysis of samples from a relatively small number of routine sampling points in most lagoons. This has been borne out by other information gathered by the Public Health Service in its general study of sewage oxidation ponds.

3. Radioiodine is apparently a satisfactory trace element for studies of the hydraulics of sewage oxidation ponds. The work of Steel and Gloyna (1), Thomas and Archibald (2) and Kaufman *et al.* (3) indicates that no major portion of I^{131} is taken up by the solids or biota present if a suitable carrier is used. This study supports that conclusion.

4. Field-scale use and field detection of radioactive tracers is a feasible means of determining hydraulic flow patterns. In any specific case, the quantity of radiotracer required, the cost, and the possibility of safe use, are factors which will determine the practical applicability of this method.

Acknowledgments

The generous assistance of the South Dakota State Health Department and the City Engineer of Philip is gratefully acknowledged.

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LANGDON PEARSE DIES

Langdon Pearse, Sanitary Engineer, Metropolitan Sanitary District of Greater Chicago, and one of the Committe of One Hundred which founded the Federation, died July 20, 1956. He was one of the first to be named an Honorary Member of the Federation (1942) and an early recipient of the Charles Alvin Emerson Medal (1947). A prodigous reader and an avid collector of technical data, he was a prolific writer of articles for technical publications and an abstractor of considerable capacity.

Mr. Pearse was born in Boston, Mass., November 12, 1877. He received an A.B. degree from Harvard College and both B.S. and M.S. degrees from Massachusetts Institute of Technology. Employed in water and sewage works in New England, Ohio and California he became associated with the Sanitary District of Chicago in 1909. During the following 47 years he engaged in development work on sewage treatment and industrial wastes, pioneered studies on the activated sludge process, and was responsible for much of the sewage treatment plant design work for the District. He also handled the sanitary engineering aspects of the Lake Michigan diversion question.

A member of many learned and professional societies, Mr. Pearse served for 10 years as Chairman of the Committee on Sewerage and Sewage Treatment, American Society of Civil Engineers, and for 20 years as Chairman of the Committee on Sewage Treatment, American Public Health Association. He served the Federation on the Publications Committee, the Post-War Planning Committee and was Cochairman of the Subcommittee that prepared Manual of Practice No. 2, "Utilization of Sewage Sludge as Fertilizer." At the time of his death he was a member of the Sewage and Industrial Wastes Practice Committee.

Those who have had the privilege of acquaintance with Mr. Pearse will always remember his outstanding personality and professional productivity, while all will encounter the marks of his many professional accomplishments in the sanitary engineering field.

PROTOZOA AND ACTIVATED SLUDGE

By Ross E. McKinney and Andrew Gram *

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Although protozoa have long been recognized as playing a definite role in the proper functioning of activated sludge, their exact role and interrelationships have never been fully defined. There is little doubt that failure to properly understand the functioning of the various protozoa and bacteria has often resulted in poor design and operation of not only domestic sewage treatment plants but also industrial waste treatment plants. The following study was made to delineate the role of the protozoa and to interpret the results in terms of practical treatment plant operations.

Previous Work

The first studies on protozoa in activated sludge consisted of microscopic observations of changes in species as floc developed. Buswell and Long (1), Agersborg and Hatfield (2) and Barritt (3) noted that there was a definite succession of protozoa during the development of activated sludge. During the initial stages of aeration the flagellated protozoa predominated; but with the increased development of floc the flagellates gave way to the free-swimming ciliates. As the activated sludge reached peak efficiency, the stalked ciliated protozoa had come into predominance over the free-swimming ciliates. Other investigators attempted to relate the efficiency of the activated sludge system to the number of protozoa in the mixed liquor. Lackey (4) and Jenkins (5) found that there was little correlation between the protozoan population and the degree of purification. This was further substantiated by the recent work of Baines *et al.* (6). While numbers were not found to be important, Cramer (7) put forth the concept that protozoa were essential for optimum purification and that routine microscopic examinations for the presence of the protozoa, *Vorticella*, could be used as an index of a well-operating activated sludge.

Attempts to distinguish the role of the protozoa from that of the other microorganisms in the floc have been made by using toxic chemicals to kill the protozoa and then noting the differences between the treated and untreated samples. Heukelekian (8) and Heukelekian and Gurbaxani (9) used this method to demonstrate that the absence of protozoa resulted in increased effluent B.O.D. and turbidity. While working with pure culture bacterial sludge, *Zoogloea ramigera*, Butterfield (10) added the protozoan, *Colpidium*, to one unit and obtained a more efficient system. The most extensive research on protozoa has been conducted by Pillai *et al.* (11)(12)(13)(14)(15)(16) in India. They advanced the concept that protozoa were the primary agents in the stabilization of organic matter by activated sludge.

Thus, three concepts of the role of protozoa in activated sludge have been developed by previous investigators:

1. Protozoa are of secondary importance, acting only as polishing agents with regards to effluent B.O.D. and turbidity.
2. Protozoa are of equal importance with bacteria as purifying agents.

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3. Protozoa are the primary purifying agents with bacteria acting as secondary agents.

Classification of Protozoa

Protozoa are divided into five classes:

1. *Sarcodina*
2. *Mastigophora*
3. *Sporozoa*
4. *Ciliata*
5. *Suctoria*

Of these five classes only three are of any importance in activated sludge: *Sarcodina, Mastigophora* and *Ciliata.* The classification of protozoa is based primarily on the method of motility, which is easy to determine microscopically.

The *Sarcodina* move by means of pseudopodia, commonly called a "false foot." The pseudopodia are formed by shifting protoplasm in the flexible cell membrane. The most common *Sarcodina* are the *Amoeba.* The *Sarcodina* engulf solid food particles, hydrolyze them and absorb them through the cell wall. They also absorb soluble food directly through the cell wall.

The *Mastigophora* move by means of one or more long flagella. The *Mastigophora* can be subdivided according to their method of metabolism: holophytic, soluble substrate, and holozoic, primarily solid substrate. The holophytic *Mastigophora* are further subdivided into the photosynthetic, energy derived from sunlight, and the chemosynthetic, energy derived from metabolism of organic matter. *Euglena* are photosynthetic holophytic *Mastigophora,* while *Chilomonas* are chemosynthetic holophytic *Mastigophora.* The holozoic protozoa are chemosynthetic and are capable of deriving energy from soluble as well as solid food. *Oikomonas* are a holozoic *Mastigophora.*

The *Ciliata* move by means of many short cilia and utilize organic particulate matter for food. The *Ciliata* are subdivided into the free-swimming forms and the stalked forms. *Paramecia* and *Tetrahymena* are examples of free-swimming ciliates and *Vorticella* of stalked ciliates.

Metabolism and Growth

The primary purpose of metabolism is to supply the necessary building blocks and the energy required to produce protoplasm for new cells. The growth of any microorganism, whether protozoa, bacteria, algae, fungi, etc., is dependent upon the metabolic requirements of the organism, the chemical nature of the substrate and the physical environment. Each species of microorganisms has its own definite metabolic requirements. Thus, for a given set of environmental conditions the growth of a pure culture of a single species of microorganisms in a dilute substrate such as encountered in most liquid organic wastes is controlled by the quantity of metabolite in solution.

The growth of two species of microorganisms both capable of ultilizing the same substrate will depend upon their respective rates of metabolism. If both species are the same size and metabolize at the same rate, their growth will be equal. If both species are the same size but one metabolizes faster than the other, the faster metabolizing species will predominate. If the two species are of unequal size but metabolize at the same rate, the smaller species will produce greater numbers but the mass of protoplasm will be equal. Thus it can be seen that the mass of cellular protoplasm is the correct corollary for determining true competitive action rather than numbers of organisms which has been used so extensively in the past.

The growth of two species of microorganisms which do not utilize the same components of the substrate is the same as if the two species were being grown separately. The two species are not competing for food and grow independently of each other.

The third case of growth is that of two species of microorganisms, one species predatory to the other. The growth of the prey is dependent upon the substrate while that of the predator is dependent upon the prey. In a completely soluble substrate the prey will grow rapidly, followed by the predator. As the number of predators increases, the demand on the prey increases until the prey is extinct. Needless to say, the predator also soon becomes extinct. In an environment where there is a hiding place for the prey such as floc or other particulate matter the predator is slowed down in its search for prey and extinction is prevented.

The basic corollaries of microorganism growth cited previously are discussed in detail by Gause (17). He presents the complete mathematical evaluation of growth, both non-competitive and competitive. From these basic corollaries it is possible to predict the fate of the various microorganisms in any biological waste disposal system. While the ensuing discussion and data will primarily be concerned with protozoa and activated sludge, it should be remembered that the same phenomena are occurring in other types of waste disposal systems and in the stream itself.

Protozoa, bacteria, algae and fungi are the common microorganisms which gain entrance to waste disposal systems, primarily from the soil. Their survival depends upon their ability to successfully compete for food. The algae do not predominate primarily because of their need for sunlight. The fungi are affected by many factors and often predominate over the bacteria. Since the bacteria and fungi belong to the same family of microorganisms, it is actually wrong to speak of them as being separate groups; but common usage has necessitated such distinction. Since the bacteria predominate over the fungi under normal environmental conditions, let us consider the competition of protozoa and bacteria with the understanding that the use of the term "bacteria" also includes fungi.

The bacteria are dependent upon soluble food. They have extracellular enzymes which are capable of converting solid organic matter into soluble organic matter. Their size, averaging 1.5×1.0 microns, is such that they require very little organic matter to produce a new cell and are able to produce tremendous numbers on very little food in a very short period of time. One part per million of organic matter is capable of producing 10^6 bacteria per milliliter.

Considering the metabolism of the bacteria and the protozoa, it can be seen that the *Sarcodina* and the chemosynthetic holophytic *Mastigophora* must compete with the bacteria for their food; while the holozoic *Mastigophora* and the *Ciliata* are predators on the bacteria. At the start of an activated sludge system, the food concentration is high and the population of any group of microorganisms is small. As a result all organisms should be able to grow with the *Sarcodina* and the chemosynthetic holophytic *Mastigophora* being the predominate protozoa during the early phases. The small size of the bacteria and their low metabolic requirement permit them to obtain a larger and larger share of the organic matter as their numbers increase. Competition of this type is such that with the continuous reseeding, as is practiced in activated sludge, the bacteria cannot completely eliminate the holophytic protozoa. The numbers of holophytic protozoa are greatly reduced by this competition and they can be considered as removed as far as their practical significance is concerned.

The holozoic protozoa must wait until the bacteria increase to sufficient numbers before they can find enough food to grow. Thus, the number of holozoic protozoa always lags the num-

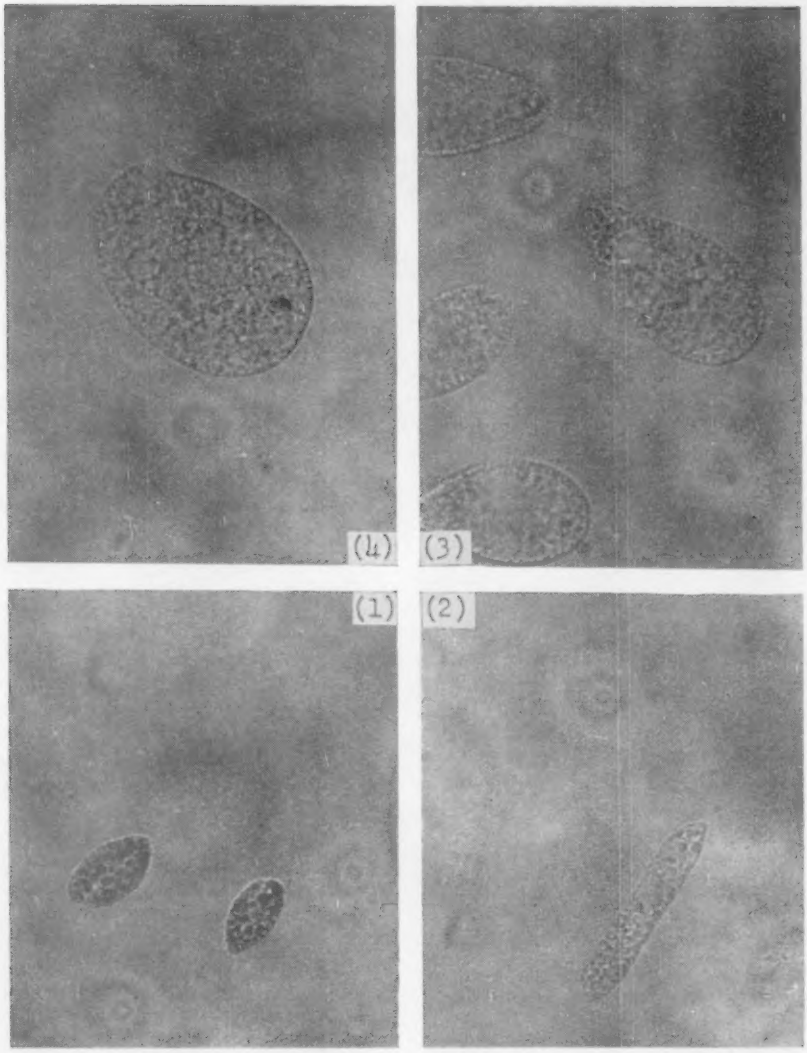

FIGURE 1.—Photomicrographs of protozoa studied (magnified approximately 3600 times), (1) *Chilamonas paramecium*, (2) *Euglena gracilis*, (3) *Tetrahymena gelii*, and (4) *Glaucoma scintillans*.

ber of bacteria in relation to their growth phases. The tiny holozoic flagellates grow first because of their lower energy requirements; but the ciliates overgrow them as a result of the ciliates' ability to obtain food more rapidly.

While previous investigations and theoretical concepts tended to affirm the general relationships between the protozoa and the bacteria, it was felt that laboratory experiments were necessary to demonstrate the competition and survival of the holophytic flagellates and the ciliates with bacteria under well defined and controlled

conditions. The following laboratory studies were made with that purpose in mind.

Experimental Method

In order to determine the relationships which exist between the protozoa and the bacteria making up the floc in activated sludge systems, the experiments were set up under the concept of "minimum conditions." "Minimum conditions" were established as (a) a completely soluble, nutritionally balanced substrate; (b) a mixture of bacteria isolated from activated sludge; and (c) a pure culture of the protozoa being studied. A completely soluble substrate was used to prevent the formation of a "pseudo" floc in the aeration unit resulting from agglomeration of colloidal solids rather than the microorganisms. All floc formed during these experiments was the direct result of metabolic activity of the microorganisms in the mixed liquor. The substrate had the following formula:

Nutrient broth, Difco, 200 p.p.m.
Glucose, 200 p.p.m.
Potassium phosphate, monobasic, 110 p.p.m.
Ammonium sulfate, 100 p.p.m.
Sodium chloride, 30 p.p.m.
Potassium chloride, 7 p.p.m.
Magnesium sulfate, 5 p.p.m.
pH adjusted to 7.2 with N/1 NaOH.

The 5-day B.O.D. was approximately 290 p.p.m.

Recent investigations (18) had

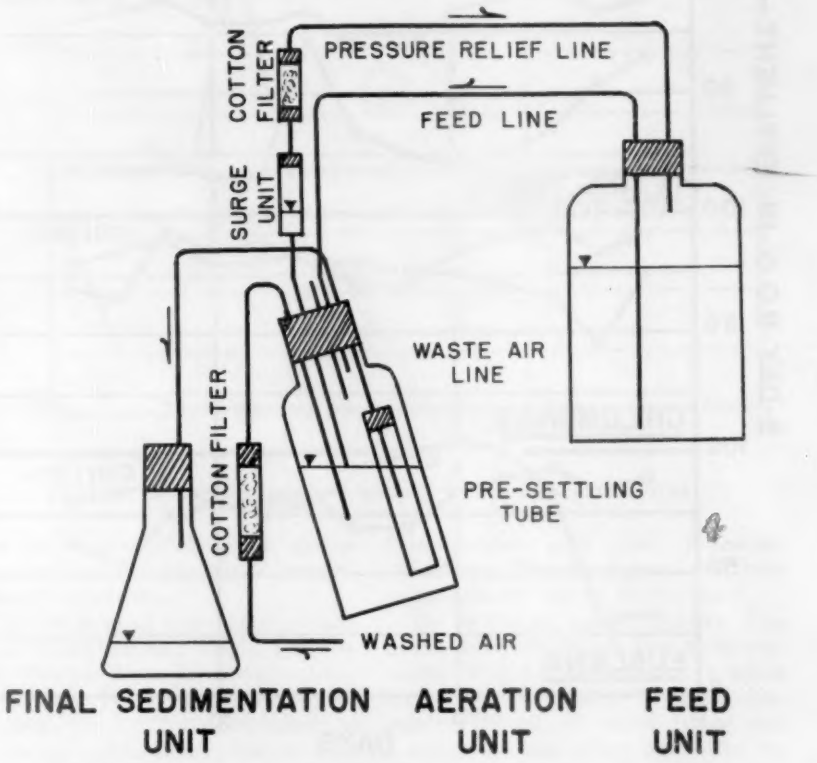

FIGURE 2.—Schematic diagram of laboratory continuous flow unit.

shown that under proper environmental conditions most of the bacteria isolated from activated sludge were capable of forming floc. Therefore, no attempt was made to isolate or to use any special floc-forming bacteria in this study. It was necessary to have only protozoa-free bacteria in the aeration system. The bacteria were separated from the protozoa of a laboratory developed activated sludge by streaking an agitated sample of sludge onto nutrient agar plates and picking off representative colonies of the predominating organisms. Since one of the components of the soluble substrate was also the major source of nutrients in nutrient agar, this in-

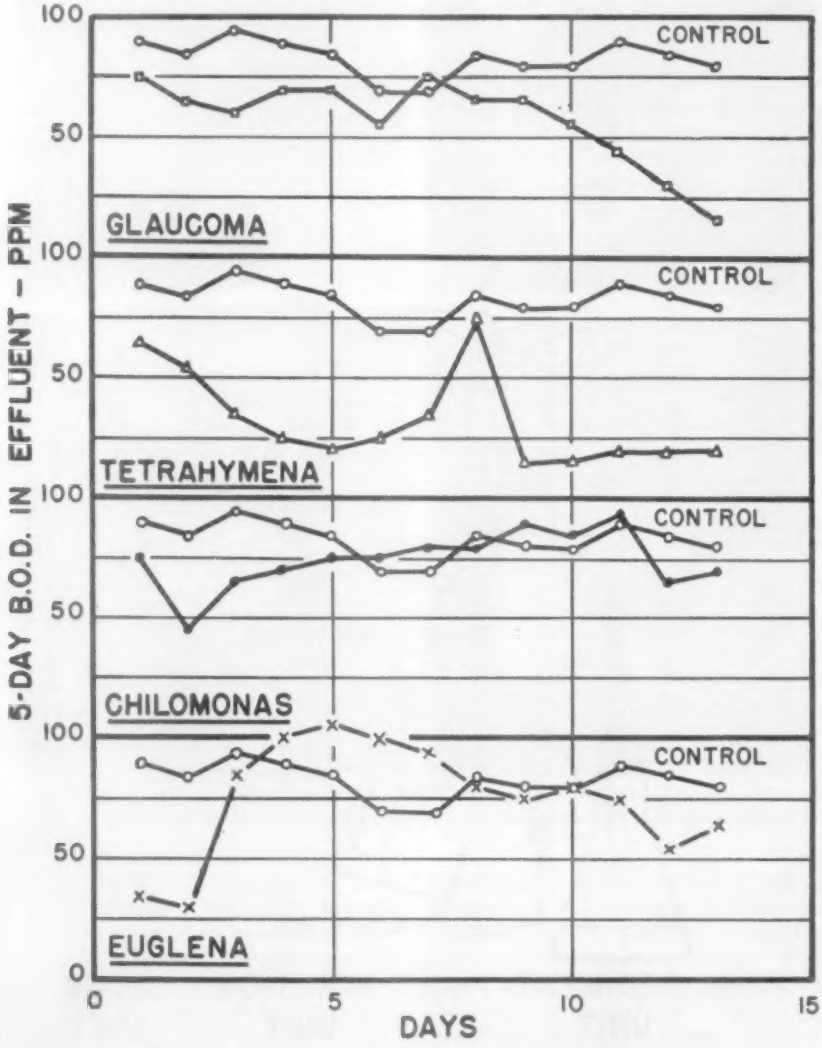

FIGURE 3.—B.O.D. of effluents from continuous flow units.

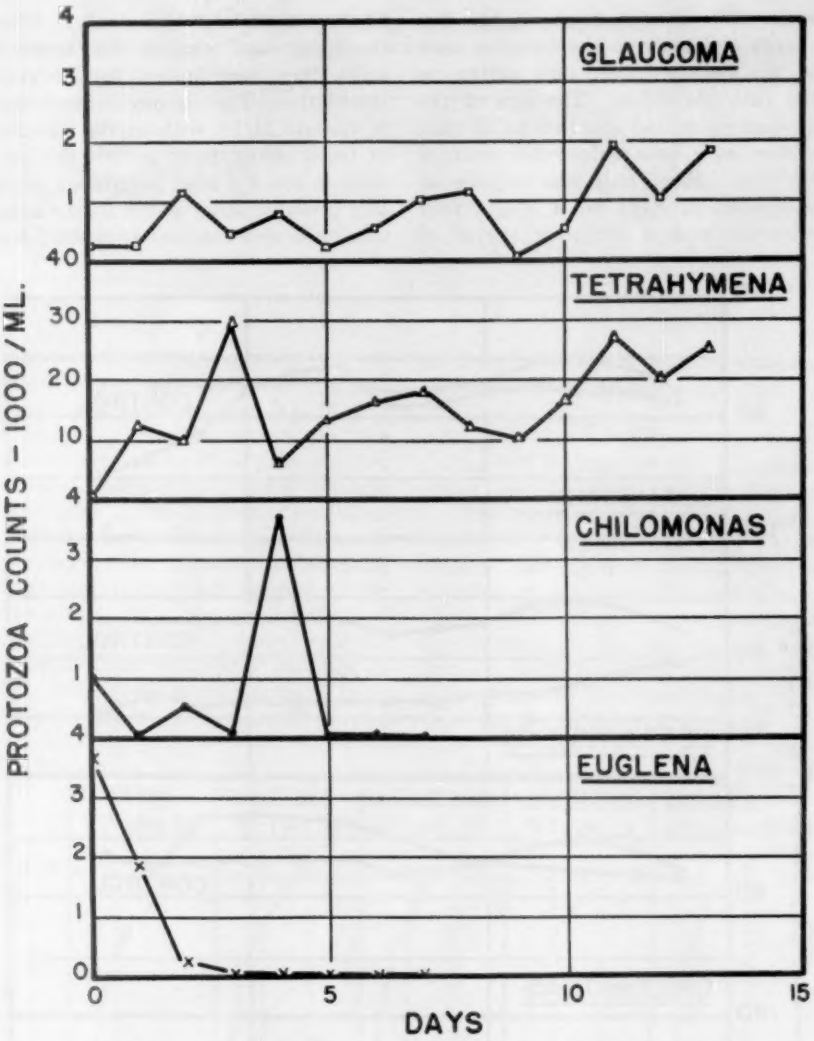

FIGURE 4.—Protozoa counts in effluents from continuous flow units.

sured the isolation of the major species of aerobic bacteria capable of metabolizing the substrates.

Pure cultures of representative species of flagellate and ciliate protozoa were obtained from the culture collection of G. W. Kidder, Amherst College, Amherst, Mass. These included as flagellates, *Chilomonas paramecium* and *Euglena gracilis*, and as ciliates, *Tetrahymena gelii* and *Glaucoma scintillans*. Photomicrographs of these organisms are shown in Figure 1.

The activated sludge systems, Figure 2, were continuous flow units consisting of a 4-l. feed reservoir which fed a 500-ml. aeration chamber containing 300-ml. of mixed liquor and a 300-ml. sedimentation unit. The entire system operated by gravity flow

with the hydraulic head on the discharge siphon from the aeration tank to the sedimentation unit acting as the rate controller. The size of the systems permitted sterilization of each system as a unit before the start of the run. Each unit was capable of operating 12 days on a single feed reservoir with a detention period of 24 hr. in the aeration tank. After sterilizing and cooling the aeration units, they were opened for bacterial inoculation. The systems were allowed to operate 24 hr. without the addition of fresh substrate to permit the bacteria to reach a high population level. The protozoa were added to the aeration units and continuous feeding was

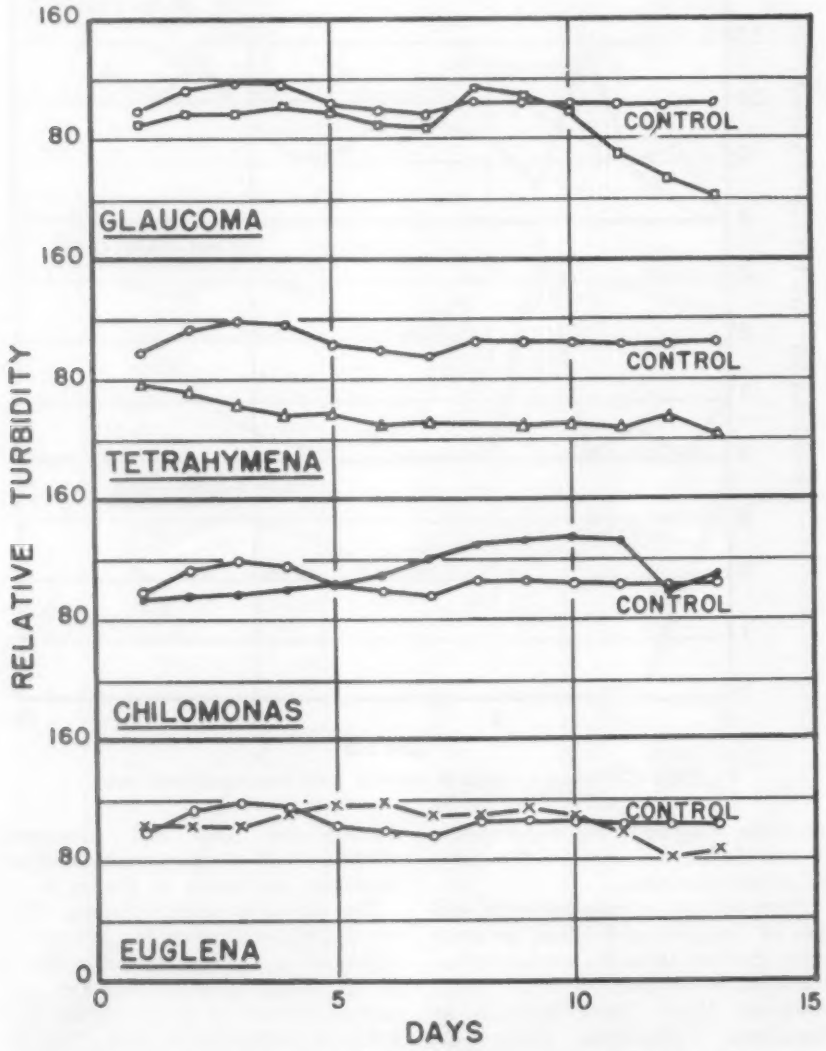

FIGURE 5.—Relative turbidity in effluents from continuous flow units.

TABLE I.—Aeration System After 12 Days of Operation

Organism	Mixed Liquor Susp. Solids (p.p.m.)	B.O.D. (p.p.m.)		Protozoa (No./ml.)	
		Unfiltered Effluent	Filtered Effluent[1]	Effluent	Mixed Liquor
Control	400	79	23	0	0
Tetrahymena	650	20	23	25,300	17,300
Glaucoma	580	15	14	1,880	3,360
Chilomonas	560	68	22	0	0
Euglena	390	65	14	0	0

[1] Microfiltered.

started. Composite samples of the effluents were collected over a 24-hr. period and analyzed for B.O.D. and turbidity. Protozoa counts in the effluent were made from grab samples collected while changing the sedimentation flasks. After 13 days of operation samples were removed from the aeration units and placed in Warburg flasks containing fresh samples of the substrate. The oxygen utilization characteristics of each sludge were determined from continuous readings on the Warburg Respirometer. Suspended solids determinations and protozoa counts were made on samples of the remaining sludge.

Results

The B.O.D. data of the composite effluent samples are shown in Figure 3. The control sample reached equilibrium very rapidly with only a slow increase in efficiency during the remainder of the run. The units containing the ciliates showed greater B.O.D. removals than the control unit and a definite downward trend as the sludges became more stabilized. The flagellate units showed a sharp dip

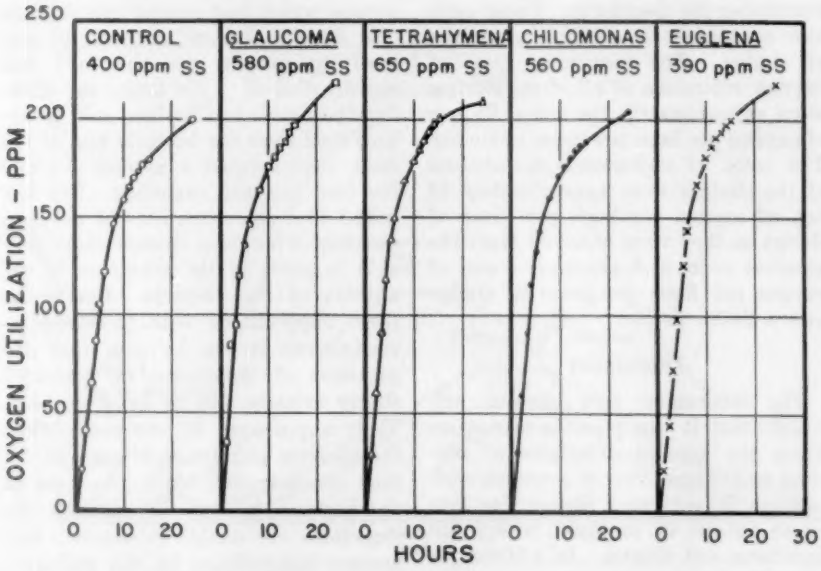

FIGURE 6.—Oxygen uptake by activated sludges from continuous flow units.

and then a rise approaching the level of the control. Variations in effluent B.O.D. were found to follow closely the number of protozoa in the effluent as shown in Figure 4. Relative turbidity measurements on the effluent samples were made with a Coleman Nephlometer using 100 p.p.m. of diatomaceous earth as a standard and are shown in Figure 5.

Samples of the mixed liquor were analyzed at the end of the run and the data are shown in Table I. Membrane * filters were used to determine if the source of the B.O.D. in the effluent was related directly to the organisms or to unused substrate. The membrane filter retained all of the bacteria and the protozoa while permitting the soluble substrate to pass. Analyses of the effluent before and after filtration yielded the amount of B.O.D. directly attributable to the microorganisms.

The oxygen utilization curve shown in Figure 6 followed the general trend of the other data with the sludges containing the ciliates utilizing oxygen more rapidly than the control or units containing the flagellates. These units also contained the largest quantities of sludge. The maximum rates of oxygen utilization of all of the sludges were approximately the same, 65 mg. of oxygen per hour per gram of sludge. The rates of endogenous metabolism of the sludges were approximately 10 mg. of oxygen per hour per gram of sludge as they were removed from the aeration units and averaged 4 mg. of oxygen per hour per gram of sludge over a 24-hr. period.

Discussion

The laboratory data showed primarily that it was possible to demonstrate the general principles of survival and competition of protozoa with bacteria in activated sludge for two major groups of protozoa, holophytic flagellates and ciliates. In addition to affirming the work of previous investigators, it helps to tie together certain field observations with the theoretical concepts, a technique much needed in the field of sanitary engineering where theory is often regarded as having no relationship whatsoever to field practice.

The principles of bacterial flocculation and stabilization as set forth by Butterfield (10) were once again demonstrated in the control unit. The various pure culture bacteria in the control unit utilized the soluble organic matter, produced new cells and underwent flocculation in a manner similar to normal activated sludge. But unlike normal activated sludge, the pure bacterial floc did not clarify the effluent completely upon quiescent settling. The motile, actively metabolizing bacteria remained in the supernatant after the floc had settled. These motile bacteria were found to be responsible for the major portion of the effluent B.O.D.

Adding the holophytic flagellates to the pure bacterial floc permitted evaluation between two different biological groups which had similar metabolism. The flagellates were not able to successfully compete for the food and rapidly died off. The larger size of the flagellate gave less surface area to absorb food than the bacteria and at the same time created a greater demand for food per unit organism. The low initial food concentration did not help the flagellates even though they were able to grow in the substrate in the absence of the bacteria. Combining these observations with previous investigations it can be seen that the presence of flagellates in activated sludge systems will be brief at most. Their appearance will be made when the bacteria population is low and the food concentration high. As soon as the bacteria increase in numbers the flagellates are unable to compete and become insignificant in the activated sludge.

* "Millipore" brand membrane filter.

On the other hand the ciliates grew quite satisfactorily in the presence of the pure bacterial floc. The free-swimming ciliates fed on the bacteria, and increased in numbers throughout the test run. The ciliates lived to a large extent on the free-swimming bacteria, reducing the effluent turbidity and B.O.D. to levels encountered in normal activated sludge systems. The presence of floc appeared to retard the ciliates in their search for food and, thereby, to limit the rate of growth. The resultant equilibrium between the bacteria and the ciliates was mutually favorable. Together they produced more floc than the bacteria alone, a clearer effluent, a more stable effluent and a more rapid rate of oxygen uptake. Thus, it becomes obvious that the ciliates play a very important role in the proper operation of activated sludge.

The fact that the ciliates were able to grow in the substrate in the absence of bacteria but not sufficiently to give a satisfactory oxygen uptake in Warburg studies adds additional information contrary to the concept that the protozoa are the primary purifying agents in activated sludge. In the system studied, as in most, if not all activated sludge systems, the bacteria were the source of food for the ciliates, not the original organic substrate. Actually, the bacteria utilize the substrate and are the primary agents of stabilization. The protozoa act as population stimulators by removing the excess bacteria which are formed, permitting a lower bacteria-substrate equilibrium and a more active floc to result.

Naturally, the question arises as to how many ciliates are required to produce a good activated sludge. There is no answer to that question since it depends upon the system itself. This has been clearly pointed out by previous investigators who have tried to correlate protozoa numbers to efficiency and have found no correlation to exist. Numbers of protozoa in a system are meaningless because it is impossible to tell whether the microorganisms are increasing or decreasing. As a given activated sludge system becomes more efficient the numbers of

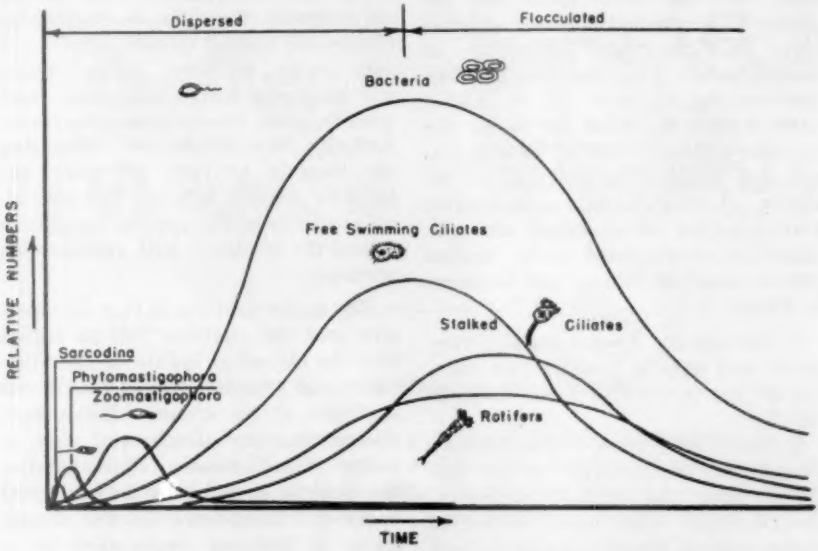

FIGURE 7.—Relative predominance of microorganisms in activated sludge systems.

any type of protozoa rise, reach a peak and then decline. Two samples taken at two definitely different operating efficiencies can yield the same number of a given species of protozoa. Thus, it is obvious that protozoa counts in themselves cannot be used as an index of efficiency.

Practical Significance

More important to the treatment plant operator is the type of protozoa present. As indicated previously, there is a definite succession of protozoa as activated sludge is formed and becomes more efficient. Knowledge of the various protozoa and their significance can be used as a valuable guide to better activated sludge operation. Observations of the protozoa can be made quickly with a microscope of only 100 power. These observations reflect the immediate condition of the sludge. Industrial waste systems fed unusual or toxic organic compounds require careful control to insure continuous operation at maximum efficiency. Since the protozoa are more sensitive to toxic compounds than bacteria, observations on the change in protozoa from normal levels give an immediate indication of trouble before it has had time to affect the bacteria.

Each operator must determine the protozoa characteristics of his own system and relate their activities to efficiency. A general guide as to relative predomination of protozoa and efficiency in an activated sludge system can be stated as follows and is shown in Figure 7.

1. *Sarcodina* predominate very rarely and only in systems just starting or just recovering from complete toxicity.

2. The holophytic *Mastigophora* (flagellates) predominate at low efficiency when the organic concentration is high. In some industrial wastes systems where the organic load is high, the efficiency may be mathematically high but the indication is that the effluent still contains a high concentration of organic matter.

3. The holozoic *Mastigophora* (flagellates) arise as the holophytic flagellates decrease. They indicate an only slightly more efficient system and efforts to distinguish between the two types of flagellates is not warranted by the results.

4. The free-swimming *Ciliata* (ciliates) are found when there are a large number of free-swimming bacteria. The efficiency of the system when the numbers are very high is approximately 50 per cent. They can indicate a fairly efficient system or a poor one. The key is in the other types present. Flagellates and free-swimming ciliates are at the low side of the efficiency scale while the presence of stalked ciliates and higher animal forms such as rotifers indicates the high side of the scale.

5. The presence of stalked ciliates indicates an activated sludge with a low B.O.D. effluent. The stalked ciliates arise as a result of the number of available bacteria being reduced below the demands of the free-swimming ciliates. Having lower energy requirements than the free-swimming ciliates the stalked ciliates survive. A very stable activated sludge system will have very few stalked ciliates and, usually, no other protozoa forms. Actually, the ciliates are measuring the bacteria activity; but since the bacteria activity reflects the biochemical condition of the system, the ciliates reflect the efficiency with considerable accuracy.

The major problem is that the operator and the engineer fail to realize that the biological indices of operation reflect the complete and instantaneous condition of the system. Microscopic observations are simple and easy to make. The protozoa characteristics are obvious to even the least trained operator. Confidence in the significance of protozoa observations on a routine basis is difficult to obtain but, once obtained, it is never lost.

Summary

The work of previous investigators was correlated with the theoretical concepts of competition and predomination between species by laboratory demonstrations. The succession of protozoa as observed in the formation of activated sludge was discussed from the aspect of operational control. The significance of the protozoa to the optimum operation of activated sludge was emphasized.

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National Library of Medicine Established

A recent law has established a National Library of Medicine in the U. S. Public Health Service and has transferred all functions of the Armed Forces Medical Library to this new library.

Location of the library has not been definitely selected.

PILOT-PLANT STUDIES OF FROTHING IN SEWAGE TREATMENT PLANTS

By L. A. Munro, M. Yatabe, and W. J. Abrams

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The problem of foaming in sewage disposal is one of continuing importance. Russell (1) has described foaming as "a hazardous nuisance which at times not only covers the entire aeration area to a depth of 10 ft. but spills out over the tank walls, killing vegetation and making walks and hand rails slippery and dangerous. In addition, anything more than the gentlest breeze carries the stuff to considerable distances causing further hazard and nuisance."

There are several recorded instances when frothing was proven to be due to, or associated with, a high concentration of syndets. In other cases the foaming could not be blamed on the detergents present in low concentrations. Hood (2) cites Gowdy as having stated "the unaerated primary effluent will not foam to amount to anything, but after it has been aerated for 2 to 3 hr. it can be made to foam. Detergents do not act that way."

Data on the foaming tendency of sewage at different stages of treatment are very limited. This paper reports on experiments designed to give a quantitative comparison of the frothing ability of raw sewage, primary effluent, mixed liquor, activated sludge final effluent, trickling filter effluent, and the supernatant from anaerobic digestion. The results of some experiments on the effect of added syndets are included. The study was made on Kingston sewage processed in the experimental sewage treatment plant of the Sanitary Engineering Laboratories, Queen's University.

The experimental pilot plant consisted of two identical and parallel systems. Each system included a primary clarifier feeding in parallel an activated sludge unit and three trickling filters. A 2-in. pump supplied a constant 50 g.p.m. of municipal raw sewage which was divided into the two systems. The effect of any added modification to one of the systems can be subjected to continuous comparison with the control.

The 27-ft. rectangular primary tanks had a theoretical detention time of 1 hr. Each activated sludge unit consisted of two 120-gal. aeration tanks in series, and a vertical final settling tank. Sludge return was by means of an air lift pump. Air at 3 p.s.i. was supplied by a centrifugal blower to the diffuser tubes. Detention time, normally 3 hr., could be varied between 2 and 10 hr. The trickling filters in each system had an effective height of 8 ft. and consisted of two 2-ft. diameter units and one 3-ft. diameter unit. One of the small units had restricted ventilation and the other filters were completely aerated. Feed was applied by rotary distributors, and each filter had a final settling tank.

A battery of six separate digestion tanks provided with temperature controls was available for anaerobic studies.

Measurement of Frothing Ability

Several different methods of measuring frothing were tested on sewage and aqueous solutions with low concentrations of syndets. Some of these

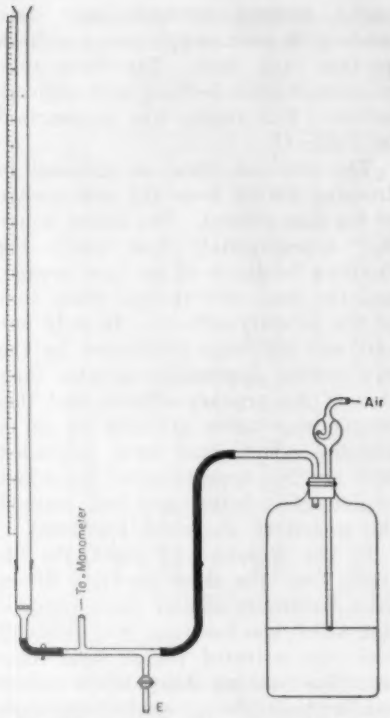

FIGURE 1.—Froth-column apparatus for measuring the height of froth formation.

methods were not sensitive, and others proved to be unsuitable for solutions containing sludge.

The apparatus chosen for these studies is shown in Figure 1. It consisted of a 16-mm. diameter pyrex glass column 114 cm. in height connected by a 24/40 standard taper joint to the base, which contained a sintered disc of medium porosity. The froth column can be surrounded by a jacket for temperature control when necessary.

Froth is produced by forcing carbon dioxide-free air through the sintered disc and a 50-ml. sample of the sewage or aqueous solution. The pressure is kept constant at 30 mm. of mercury by means of a needle valve on a by-pass outlet. At this pressure a flow rate of 200 ml. of air per minute is obtained. A fixed zero line was placed on the column at the level assumed by the top surface of a sample of distilled water at 20° C. when air was bubbled through it at the fixed rate. Froth heights with a 50-ml. sample were read on a millimeter scale from the fixed mark on the froth tube. Readings were taken every 5 sec. for 30 seconds.

With low concentrations of frothing agent the froth height will reach a maximum in a few seconds, decreasing to a constant or minimal value. As detergent concentration is increased, the height and time to reach the maximum also increase. The fall in froth height from a maximum is doubtless due to the adsorption of detergent agent in the froth until the depletion of the mother liquor causes a decrease in the frothing ability. With the collapse of some of the froth, enrichment of the mother liquor will result and frothing increase. When the rate of collapse equals the rate of production of the froth, a constant level will be obtained. In the experiments reported herein, frothing ability was estimated from multiple determinations of the maximum height during 30 sec. In any determination, readings were discontinued if the froth became separated into sections. The frothing characteristics of the solution can be represented by a curve obtained by plotting maximum froth height during 30 sec. *versus* concentration.

TABLE I.—Frothing Heights for Aqueous Solutions of Sodium Lauryl Sulfate

Syndet Conc. (p.p.m.)	Height, Avg. Max. (cm.)
5	4.8
8	7.7
13	27
16	44
10	13
12	20.7
14	26
15	43.3
17.5	53
20	60
25	67

The results obtained with sodium lauryl sulfate in water are typical and are given to illustrate the method and the degree of accuracy (Table I).

A plot of the maximum froth height against concentrations of syndet gives a sigmoid-type curve (Figure 2). For low concentrations (1 to 10 p.p.m.), and at concentrations greater than 20 p.p.m., the froth height changes slowly with an increase in syndet concentration. In the middle of the curve (around 15 p.p.m.) frothing is very sensitive to changes in concentration.

Frothing Characteristics of Sewage

Samples of raw sewage, primary effluent, mixed liquor, activated sludge final effluent, the filtrate from trickling filters, and the supernatant liquid from the anaerobic digesters were collected at the same time, at intervals, during a two-month period and the frothing characteristics determined for each. Several determinations were made with each sample using a fresh portion each time. The froth tube was rinsed twice between each determination. The results are summarized in Table II.

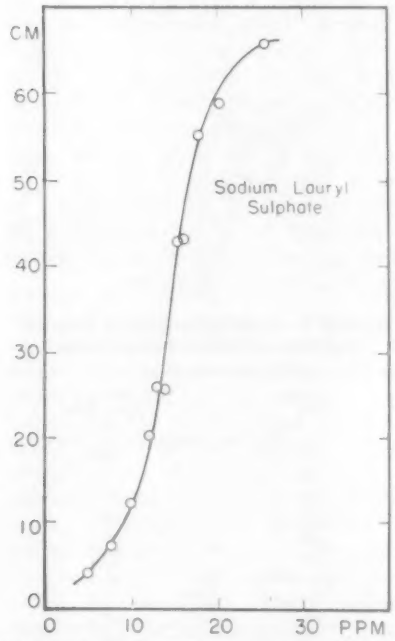

FIGURE 2.—Sigmoid-type curve for froth height *versus* detergent concentration.

The averages show an increase in frothing ability from the raw sewage to the final effluent. The mixed liquor had approximately four times the frothing tendency of the raw sewage, and the final effluent four times that of the primary effluent. In only one case was the froth production by the raw sewage appreciably greater than that of the primary effluent, and this sample was taken at 9:30 AM on a Monday which may have coincided with the first appearance of the influx of detergent, before any had reached the secondary stages of treatment.

In the experimental plant, the filtrates from the three trickling filters gave essentially similar froth production which was less than that obtained with the activated sludge final effluent. The frothing ability of the supernatant from the anaerobic digesters was in every case much greater than at any part of the activated sludge process.

The present work affords quantitative evidence of the increase in the frothing ability of sewage at different stages of treatment as noted by Gowdy (3). The sewage studied contained detergents in amounts which varied from day to day.

Surface Tension of Sewage Fractions

Many surface active reagents are excellent frothers. With most detergents, frothing occurs over a range of detergent concentrations where the surface tension is changing rapidly (4). Low surface tension reduces the amount of energy necessary to stretch the bubble film, and in this respect favors frothing. Practically all common detergents lower the surface tension of water. There is, however, no correlation between the value of the

TABLE II.—Frothing Height of Sewage During Various Stages of Treatment

Raw (cm.)	Primary Effl. (cm.)	Mixed Liquor (cm.)	Activated Sludge Effl. (cm.)	Digester Supernatant (cm.)	Trickling Filters (cm.)		
					No. 1	No. 2	No. 3
15.5	12.0	30.0	—	—	—	—	—
5.0	7.0	—	20.0	—	18.4	21.1	20.6
0.6	6.0	13.2	30.0	—	23.0	12.3	—
3.5	—	—	18.0	—	—	—	—
20.0	—	—	27.0	—	—	—	—
6.5	9.2	40.0	49.0	—	—	30.0	—
3.5	10.0	26.0	54.0	—	—	—	23.3
7.4	6.8	24.0	21.0	—	15.0	11.5	—
—	—	44.0	55.0	—	—	—	—
2.8	13.2	43.0	23.3	70.0	—	22.0	29.0
3.1	2.7	37.2	46.0	63.0	—	17.7	12.0
4.6	4.8	24.3	28.3	90.0	21.0	14.0	14.0
2.8	2.9	3.9	16.7	78.0	8.6	—	—
2.4[1]	2.5	2.8	3.2	64.0	2.7	—	2.5
2.3[1]	2.4	2.6	3.0	75.0	3.6	—	—
2.8[1]	2.9	4.3	16.3	—	6.7	—	2.7
2.5	13.3	3.7	5.7	74.0	27.8	—	—
2.9	3.0	18.3	22.7	73.5	10.7	—	—
13.2[2]	2.6	3.8	4.2	67.0	28.0	—	—
1.0	9.5	19.0	—	—	—	—	—
Avg. 5.4	6.2	20.0	24.7	69.6	15.0	18.3	14.9

[1] Heavy rain.
[2] 9:30 AM samples.

surface tension and the concentration of detergent. Optimum concentrations for frothing vary from one detergent to another, and even with the same type of surface active substance the frothing will change with the length of the carbon chain.

The values of the surface tension at which maximum frothing is obtained also varies even in such a homologous

TABLE III.—Surface Tension[1] of Sewage at Different Stages of Treatment[2]

Raw	Primary Effl.	Mixed Liquor	Activated Sludge Effl.	Trickling Filters			Digester Supernatant
				No. 1	No. 2	No. 3	
55.0	57.0	63.6	56.6	—	57.0	56.0	—
42.9	51.9	60.1	61.7	—	59.4	—	—
45.3	53.4	55.5	59.4	—	59.8	—	—
43.0	65.2	61.8	59.5	—	61.2	58.8	—
42.6	54.9	58.1	59.1	—	58.5	57.9	51.0
50.6	56.8	62.4	60.6	—	63.6	55.6	55.6
55.6	53.1	59.8	62.4	61.7	55.9	56.4	57.1
49.9	55.3	57.9	65.3	68.6	—	—	55.9
49.6	64.6	66.6	72.2	—	55.3	69.3	58.2
46.9	58.1	65.1	65.7	66.4	—	—	59.6
51.1	62.5	68.3	68.0	67.6	—	61.2	—
59.1	60.1	65.3	71.8	63.0	—	—	60.1
48.5	52.6	69.6	65.9	70.3	—	—	58.6
49.8	58.9	69.9	72.2	66.1	—	—	58.9
Avg. 48.6	56.8	63.1	66.4	66.3	58.0	59.4	57.7

[1] Dynes per centimeter.
[2] Determined before frothing.

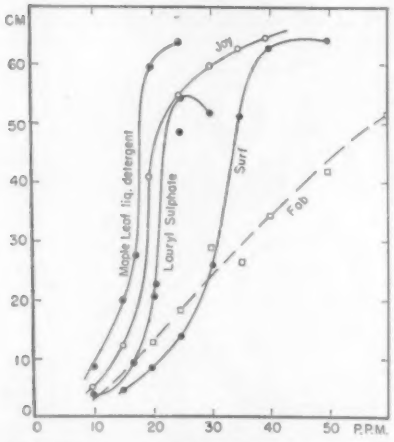

FIGURE 3.—Frothing curves for several commercial syndets in water.

series (4). The addition of electrolytes may change the surface tension and not influence the froth, or they may alter the frothing without an appreciable change in the surface tension. Non-frothing detergents may produce a low surface tension but because of multiple functional groups give poor stability to the film. It is understandable that Lynch and Sawyer (5) found no correlation between surface tension and foam production of similar concentrations of commercial syndets.

Surface tension measurements, nevertheless, do indicate changes in the medium and such information may be of interest. The surface tension of 14 of the 19 samples of the sewage at various stages of treatment (Table II) was determined by a de Nuoy tensiometer. The data are tabulated in Table III. There is an increase in surface tension from the raw sewage to the final effluent. The increase between the raw and primary effluent was quite marked except in one case only. The digester supernatants, which gave a copious froth, had an average surface tension of 57.7 dynes

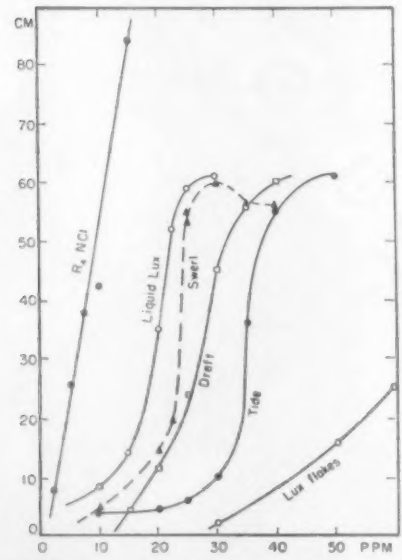

FIGURE 4.—Frothing curves for several syndets and a soap in water.

TABLE IV.—Composition of Several Syndets

Syndet	Composition	
	Chemical	Percentage
Dreft	Sodium lauryl sulfate	38.8
	Sodium sulfate	57.8
Fab	Alkyl aryl sulfonate	36.0
	Tetrasodium pyrophosphate	43.6
	Trisodium phosphate	2.9
	Sodium silicate	6.0
Joy	Mixed amide and sulfonate	62.0
Liquid Lux	Polyglycol derivative	—
Maple Leaf Liquid Detergent	Polyglycol derivative	—
Surf	Alkyl aryl sulfonate and phosphates	—
Swerl	Alkyl aryl sulfonate	33.4
	Sodium sulfate	62.6
Tide	Lauryl sulfate	19.6
	Tetrasodium pyrophosphate	3.5
	Trisodium phosphate	31.0
	Sodium silicate	7.4
	Sodium sulfate	14.8
Duz	Soap	77.0
	Tetrasodium pyrophosphate	7.8
	Sodium silicate	10.2
	Water	3.2

TABLE V.—Froth Formation of Some Soaps and Water

Lux Flakes		Ivory Flakes		Dux		Bye	
Conc. (p.p.m.)	Froth (cm.)	Conc. (p.p.m.)	Froth (cm.)	Conc. (p.p.m.)	Froth (cm.)	Conc. (p.p.m.)	Froth (cm.)
40	8	50	2.2	80	3	20	6.2
50	16	60	3	90	12	25	8.8
60	25	65	30	100	27.7	30	36.5
65	34.7	70	39	110	33	35	40.3
70	28	75	41	120	43	40	48.8
80	50	—	—	130	47	—	—
—	—	—	—	150	46	—	—
—	—	—	—	200	52	—	—

per centimeter, which was not very different from the surface tension of the primary effluent.

Frothing Ability of Some Syndets

Syndet and Water

The frothing curves for a number of commercial detergents are presented in Figures 3 and 4. The nature and composition of these syndets are given in Table IV. The frothing ability of the soaps is very much poorer than for the syndets. The soaps also show a marked inflection in the mid-range between commencement of frothing and the maximum froth height of approximately 60 cm. This is probably associated with micelle formation or change in the nature of the soap solution with concentration. Another characteristic of soap solutions is the decrease in frothing ability with time, *i.e.*, with the age of the standard soap solution. For comparative studies fresh solutions should be used. Table V gives data for soaps not shown on the graphs in Figures 3 and 4.

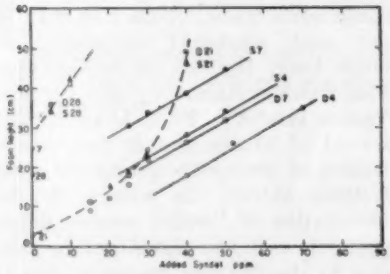

FIGURE 5.—Frothing curves for Dreft (D) and Swerl (S) in sewage.

Syndet and Sewage

Some preliminary experiments have been done in this laboratory on the effect of known concentrations of syndets on the foaming of domestic sewage at the different stages of treatment.

TABLE VI.—Syndet Effect on Frothing of Raw Sewage

Date (Mar.)	Dreft		Swerl	
	Concentration (p.p.m.)	Froth (cm.)	Concentration (p.p.m.)	Froth (cm.)
4	0	2.5	0	2.5
	40	18	30	22
	52	26	40	28
	70	35	50	34
7	0	25	0	25
	25	15.5	35	30.5
	30	22.7	30	34
	40	26.3	40	38.5
	50	32	50	44.3
11	0	0	0	0
	30	16	20	15
	40	27	25	24
	50	36.6	30	28
	—	—	40	40
	—	—	50	40.5
21	0	2.5	0	2.5
	15	9	15	11
	20	15	25	18
	30	23.5	30	24
	40	46	40	49
28	0	18	0	18
	5	36	5	34
	10	41	10	42

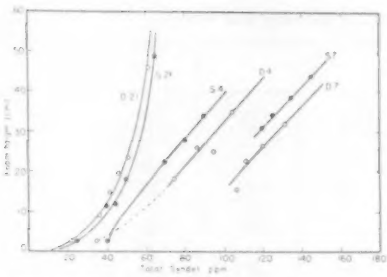

FIGURE 6.—Frothing curves for Dreft (D) and Swerl (S) in sewage, corrected for concentrations of "active" agent.

Dreft and Swerl were chosen because the chief difference is in the type of anionic agent. They were added to different samples of raw sewage, primary effluent, mixed liquor and activated sludge froth final effluent.

In each sample the froth production of the sewage sample was lower than with the same total concentrations of syndet in water alone. In all cases but one, the addition of anionic syndets increased the frothing of the sewage sample. Frothing curves for two syndets in sewage are illustrated in Figure 5. Table VI gives data on the samples of raw sewage.

The initial content of anionic "active" detergent was determined in each case by the method of Degens *et al.* (6). From these analyses and the known composition of the syndet added, total concentrations of "active agent" were calculated. The resulting frothing curves are shown in Figure 6.

Discussion

The fairly regular pattern of increasing surface tension indicated the destruction of surface active components and/or the production of substances which raise the surface tension such as salts, glycerol from the hydrolyses of fats, or possibly sugars. These changes may increase frothing by increasing the stability of the film. It is known that anionic syndets form complexes with protein materials or adsorption complexes with the suspended solids. Many syndets are oxidized readily but several, particularly the alkyl aryl-type are not (7). Donaldson (8) reports that the concentration of detergent by weight in froth amounted to 900 p.p.m. and represented 12 per cent of the total solids in the froth. In one instance when frothing occurred in the experimental plant the concentration of syndets in the collapsed froth amounted to 5,100 p.p.m.

Eckenfelder and Hood (9) state that excess aeration even without the presence of detergents causes frothing. Hood (2) has said that "There is substantial evidence that syndets are neither the prime nor sole cause of foaming." The very high frothing tendency observed in the experiments on the supernatant from the anaerobic digesters indicates that the manner in which the sewage constituents are broken down is of prime importance. Nevertheless, there is ample evidence also that the presence of syndets increases the frothing of sewage. Simpson (10) found that a sewage which gave no froth when aerated for 21 hr., frothed in 8 hr. when treated with 21 p.p.m. of nonionic detergent. When the detergent concentration was increased to 60 p.p.m. frothing occurred in 1 hr.

A study of the data and curves for the various detergents proves that the frothing tendency of a detergent solution cannot be predicted from the concentration of so-called total active constituents alone. Thus Fab with 36 per cent alkyl-aryl sulfonate had much lower frothing tendencies than Tide which contains only 19.6 per cent "active syndet." There is an average spread of 30 per cent in the concentration of detergents giving the same frothing ability. In sewage, the determination of "active anionic detergent" is still less significant in relation to the frothing tendency, due to the several additional factors suggested above.

Methods for the analysis of various mixtures of syndets have recently been published (11)(12). Their utility in the determination of the varying mixtures of detergents in sewage, has yet to be satisfactorily established.

These experiments and a review of the current literature on frothing indicate that more work should be done on the factors which cause frothing in the absence of any detergent. This can best be done with a standardized synthetic sewage which avoids the continuously changing composition encountered in domestic practice. Significant changes in composition and properties may then be detected. The effect of added syndets and their accompanying salts and water conditioners could then be evaluated.

Summary

Methods of measuring frothing ability and the stability of the froth have been adapted to determine accurately the frothing tendency of sewage at different stages of treatment.

The frothing tendency of domestic sewage increased from raw sewage to the final effluent. The supernatant liquid from the anaerobic digesters gave the greatest froth production.

The addition of domestic anionic type detergents to different sewage fractions increased the froth production. The sewage constituents decreased the frothing ability of the detergent. Determination of "active anionic agent" in sewage is of only slight value in indicating the frothing tendency.

The surface tension of domestic sewage increased from the raw sewage to the final effluent.

Acknowledgment

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Industrial Wastes

TREATMENT OF WASTES FROM A CORN INDUSTRY BY PILOT-PLANT TRICKLING FILTERS *

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The study reported here was made to develop a waste treatment and disposal process for the Bluebonnet Plant of the Corn Products Refining Company at Corpus Christi, Texas, which would produce a low B.O.D. effluent, or would permit re-use of the treated effluent.

The complete study included a comparison of the results accomplished by the "super-activated sludge treatment" method and the trickling filter method of waste treatment. This paper is restricted to reporting results and data regarding operation of the trickling filter pilot plant which was designed by Southwest Research Institute personnel, and was constructed and operated by personnel of Corn Products Refining Company.

The waste water from the Bluebonnet Plant results from the wet-milling of grain sorghum for the production of starch and related products. At the time of this study the B.O.D. of the waste varied from 500 to 2,000 p.p.m. with the average being about 900 p.p.m. The pH of the waste was predominately acid, as the result of ion exchange resin backwash which used sulfuric acid. The waste was deficient in nitrogen and phosphorus, vital nutrients for the growth of microorganisms.

Trickling Filter Pilot Plant

The design of the trickling filter pilot plant is illustrated in Figure 1. The unit consists of two trickling filters in series, preceded by a 5,000 gal. wooden equalization tank which received an aliquot portion of the total West Sewer waste water. This tank serves for pH adjustment and for retaining a weekend supply of waste for the trickling filters. Each filter was constructed of two sections of 36-in. diameter concrete sewer pipe. The media in each filter is a vertical clay block § containing vertical openings 1 in. in diameter. These blocks were stacked 6 ft. high. Each trickling filter has a 60-gal. stainless steel settling basin, from which the treated effluent is recycled to the incoming raw feed; the first filter effluent is applied to the second filter. The waste is applied evenly over each filter by a mechanical distributor.‖ Figure 2 is a photograph of the completed pilot plant.

Operation of the trickling filter pilot plant was started on December 19, 1952. The 5,000 gal. equalization tank was filled with the West Sewer waste water, and two 100-lb. feed sacks of manure were suspended inside the tank to furnish microorganisms for the biological growth on the filter media.

The raw waste was applied at a rate of approximately 0.25 g.p.m. and the

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§ "Aero-Block" made by Red Wing Sewer Pipe Corp., Red Wing, Minn.

‖ Product manufactured by the Lakeside Engineering Corp., Chicago, Ill.

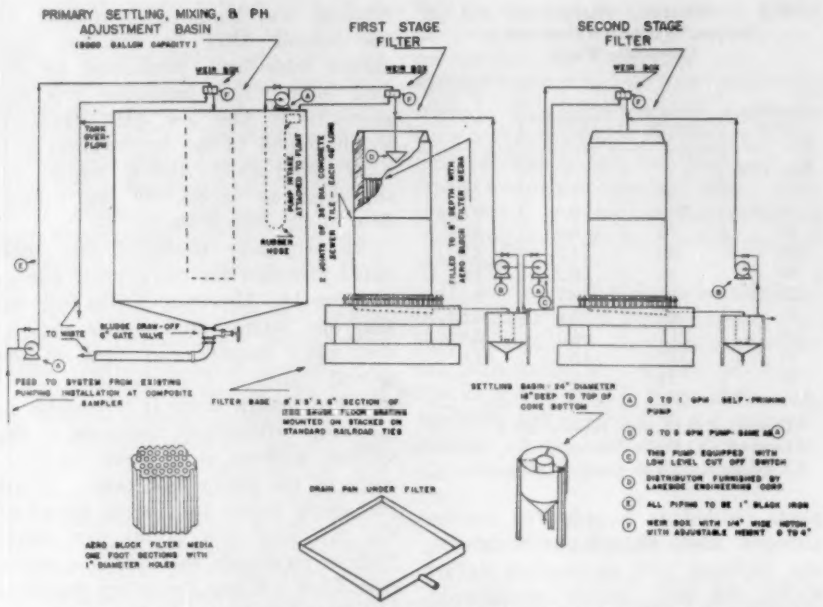
PRIMARY SETTLING, MIXING, & PH ADJUSTMENT BASIN
FIRST STAGE FILTER
SECOND STAGE FILTER
WEIR BOX
TANK OVER-FLOW
RUBBER HOSE
SLUDGE DRAW-OFF 6" GATE VALVE
TO WASTE
FEED TO SYSTEM FROM EXISTING PUMPING INSTALLATION AT COMPOSITE SAMPLER
FILTER BASE
SETTLING BASIN - 24" DIAMETER 18" DEEP TO TOP OF CONE BOTTOM
DRAIN PAN UNDER FILTER
AERO BLOCK FILTER MEDIA ONE FOOT SECTIONS WITH 1" DIAMETER HOLES

FIGURE 1.—Flow diagram for pilot-plant trickling filter treatment of corn industry wastes.

effluent was recirculated at 1.25 g.p.m., providing a recirculation ratio of 5 : 1. An analysis of several 24-hr. composite West Sewer samples (Table I) indicated that the waste was deficient both in nitrogen and phosphorus. This deficiency was based on an average B.O.D. of 900 p.p.m., which would require one part nitrogen for each 20 p.p.m. B.O.D. and one part phosphorus for each 75 p.p.m. of B.O.D. These elements are necessary nutrients for the microorganisms and were supplied daily. The initial over-all loading to the trickling filter system was approximately 1 lb. of B.O.D. per day per cubic yard of filter media. The pH was adjusted to a value between 6.5 to 8.5 daily, and soda ash was used for this purpose.

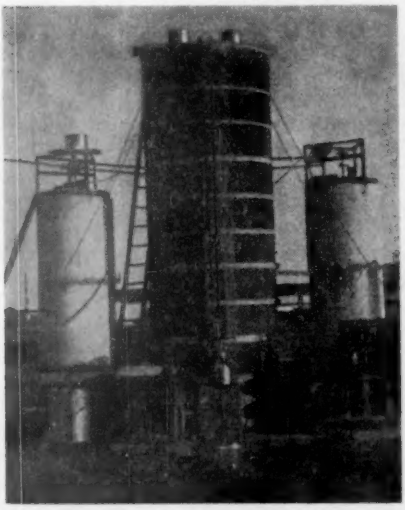

FIGURE 2.—Completed pilot-plant units.

Operating Conditions

Figure 3 presents a graph of the daily operating data during the period of plant operation. As indicated by these data, the trickling filter treatment provided good B.O.D. removals, except for the period from mid-January to February, 1953. During this period the diammonium phos-

TABLE I.—Nitrogen,[1] Phosphorus,[2] and pH Values, Samples of West Sewer Composite Waste[3]

Sampling Date	Nitrogen (p.p.m.)	Soluble Phosphorus (p.p.m.)	pH
Jan. 1953			
15	16	1.8	3.0
16–17	136	0.6	6.1
19	75	6.4	8.8
20	20	1.5	3.9
22	12	0.2	4.6
22–25	43	2.7	4.3
26	40	5.9	4.6
28	17	4.1	2.9
29	317	15.4	4.6
30	24	3.9	3.2

[1] Desired B.O.D. to N ratio = 20:1.
[2] Desired B.O.D. to P ratio = 75:1.
[3] Average B.O.D. of waste = 900 p.p.m.

phate, added to supply the needed nitrogen and phosphorus nutrients, was replaced with ammonium sulfate which did not contain phosphorus. This change caused a decrease in the over-all efficiency of the process. However, the system quickly recovered when phosphorus was again added.

During the initial operation of the trickling filter pilot plant, it was observed that the majority of the B.O.D. removal was being accomplished by the second filter; a function that should have been performed by the first filter. This condition was due partially to the low pH values of the feed and to the employment of a filter pilot-plant design which resulted in an excessively low recycle flow to the first filter.

As originally designed, the pilot plant provided for two recycle pumps (Figure 1). However, it was believed that one pump could suffice for the first filter recycle and feed to the second filter. Unfortunately, this modified design made it impossible to maintain satisfactory operation of the system, without continuous readjustment of the pump flow rates. When the single pump functioned ahead of the raw feed flow to the first filter, little or no recycle was delivered to the first filter. When the pump flow was less than the raw feed flow to the first filter, overflow of the first settling basin resulted.

On February 19, 1953, a second pump was installed in accordance with the original design of the pilot plant, and this resulted in the second filter

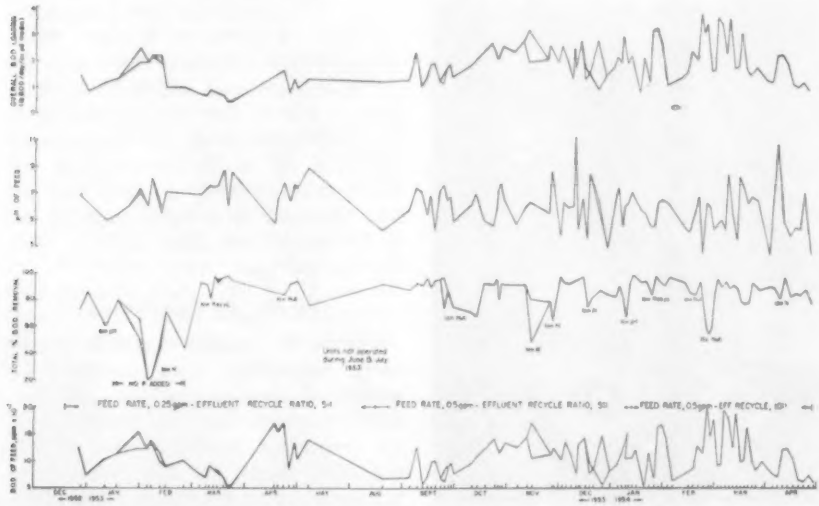

FIGURE 3.—Plot of operating data for trickling filter pilot plant.

receiving the same volume of feed as the first filter. In addition, the operation of two pumps provided each filter with an independent recycling system and, consequently, a constant recycle flow. After installation of the additional pump and close adjustment of the pH of the raw feed, the over-all B.O.D. efficiency increased to better than 90 per cent and the first filter provided a large share of the total B.O.D. removal.

Figure 3 indicates that the system continued producing satisfactory B.O.D. removals except at certain times when the other duties of the plant operator prevented adjusting the pH or adding the necessary nitrogen and phosphorus. Some trouble was experienced with the waste distributor belts breaking or coming off, which gave periods of channeled flow through the filter media. However, when these conditions were corrected the B.O.D. removal efficiencies always returned to their former levels.

It was planned to increase the raw feed flow to 0.5 g.p.m. about May 1, 1953, in order to increase the B.O.D. load to the system; however, the raw waste pump failed to operate. The pump was not repaired until July 13. During the interval, the system was fed with a solution of sugar and steep water to maintain the microorganism growth on the filter tile media. On July 13 the 0.25 g.p.m. feed rate was resumed, and on August 15 the feed rate was increased to 0.5 g.p.m. The recycle ratio of the effluent remained at 5:1. After this resumption of operation the trickling filter system generally gave satisfactory results, except for periodic operational failures caused by low pH and nitrogen and phosphorus values.

On January 13, 1954, the effluent to feed recycle ratio was increased from 5:1 to 10:1. At this time the B.O.D. load to the system varied from 2 to 4 lb. of B.O.D. per day per cubic yard of filter media, depending upon the B.O.D. value of the raw feed. With the previously mentioned feed rate and recycle ratio, the pilot plant gave satisfactory results except for about one week in February when no nutrients were added; and also during the latter part of March and the first part of April when the trickling filter pilot plant went unattended due to other duties required of the operator during this time.

It was planned to increase the load to the filter again by increasing the feed rate to 0.75 g.p.m. and running the unit until the middle of June. However, the annual plant shut-down for 1954 took place on May 1, and operation of the trickling filter pilot plant was discontinued on April 28, 1954.

Discussion of Data

Graphs were plotted showing the per cent B.O.D. removals and effluent B.O.D. produced at various influent B.O.D. concentrations. These plots illustrate the over-all treatment by the two-stage filter system.

Figure 4 presents a graphical representation of the B.O.D. of the influent feed plotted against per cent B.O.D. removed at a 0.25 g.p.m. feed rate and 5:1 ratio of recycled effluent

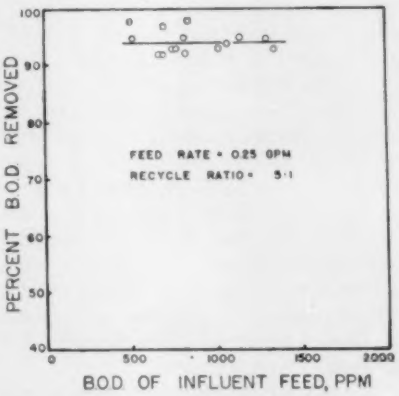

FIGURE 4.—B.O.D. removal at feed rate of 0.25 g.p.m. and recycle ratio of 5:1.

ent. The run at these conditions gave 26 sets of data and, as shown in Figure 3, the operational conditions were not optimum (*i.e.* no recycle, low pH, or insufficient nutrients) at the time nearly one-half of the data were taken. Therefore, a plot of data taken only during the time the pilot plant was run under optimum conditions is shown in Figure 4. In some cases it was difficult to determine which data should be discarded, as it was impossible to determine whether or not the biota of the media was at equilibrium after a period of low recycle, abnormal pH, or insufficient nutrients. Also, if at the time of sampling the operating conditions were abnormal it could not always be determined if the biota had been affected at that time.

The data for Figure 4 represents influent B.O.D. values between 500 and 1,300 p.p.m., with an over-all applied B.O.D. loading between 0.5 to 1.5 lb. of B.O.D. per day per cubic yard of filter media. A straight line showing 94 per cent B.O.D. removal was obtained over the entire range. This was a relatively low loading, thus the constant per cent B.O.D. removal curve had not begun its downward break. Using only those data taken when the pH of the influent feed was optimum, and when sufficient nitrogen and phosphorus were present, a rather good correlation was obtained; however, had all the data been used no pattern of data points could be obtained. It was believed that a plot of all the data does not give a true picture of what the trickling filter is capable of doing in treating the waste; it does show that when the pH and nutrient frequently were not as they should be, the trickling filter system quickly recovered when the pilot plant was again operated under proper conditions.

Figure 5 is similar to Figure 4, except that the feed rate was 0.5 g.p.m. with a 5:1 effluent recycle ratio. At

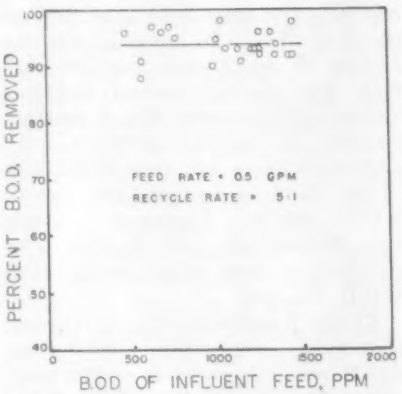

FIGURE 5.—B.O.D. removal at feed rate of 0.5 g.p.m. and recycle ratio of 5:1.

these conditions 42 sets of data were obtained and 18 were discarded for the same reasons as previously mentioned. The B.O.D. loadings at this 0.5 g.p.m. feed rate were from 1 to 3 lb. of B.O.D. per day per cubic yard of filter media. These data also indicated about a 94 per cent B.O.D. removal over the entire range of influent B.O.D. values between 500 and 1,500 p.p.m.

Figure 6 is similar to Figures 4 and 5, except that the feed rate was held at 0.5 g.p.m. with the recycled effluent ratio increased to 10:1. At these conditions 36 sets of data were taken with 15 sets being discarded. A plot of the desired data produced much the same type of curve as in Figures 4 and 5. This plot represented data at a B.O.D. loading varying from 1 to 4 lb. B.O.D. per day per cubic yard of filter media, with only a few data at the upper range. However, nearly one-half the data were obtained at a loading of about 3 lb. of B.O.D. per day per cubic yard. The B.O.D. of the influent feed varied from 500 to 1,900 p.p.m.

Figures 7, 8, and 9 are plots of data obtained during the same operating conditions as shown in Figures 4, 5, and 6. However, in these graphs the B.O.D. of the influent was plotted

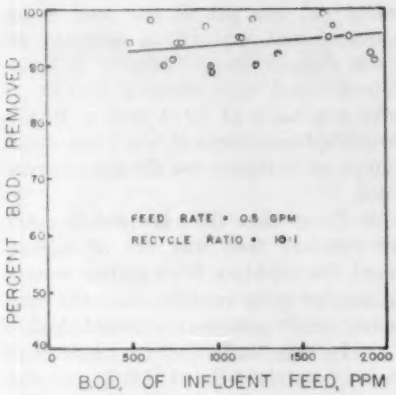

FIGURE 6.—B.O.D. removal at feed rate of 0.5 g.p.m. and recycle ratio of 10:1.

against the B.O.D. of the final effluent. From Figure 7 it appears that a final effluent B.O.D. of less than 100 p.p.m. can be obtained with B.O.D. concentrations in the waste varying from 500 to 1,500 p.p.m. A final B.O.D. of less than 50 p.p.m. can be expected if the influent B.O.D. is no greater than 600 to 700 p.p.m. This represents a flow rate of 0.25 g.p.m. with a 5:1 effluent recycle.

It appears from Figure 8 that at a 0.5 g.p.m. feed rate and a 5:1 recycle ratio an effluent B.O.D. of 100 p.p.m. or less can be maintained when

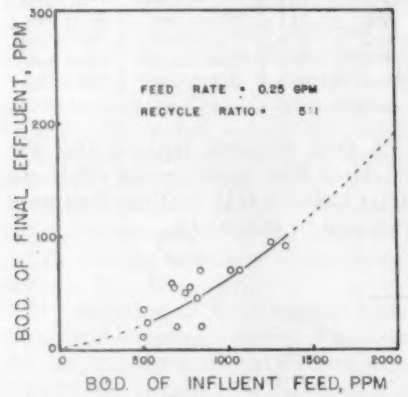

FIGURE 7.—Effluent B.O.D. at feed rate of 0.25 g.p.m. and recycle ratio of 5:1.

the B.O.D. concentration is 1,400 p.p.m. or less. Also, an effluent B.O.D. of 50 p.p.m. or less can be obtained if the feed B.O.D. concentration is 800 p.p.m. or less. Figure 9 indicates that if the effluent recycle ratio is increased to 10:1 an effluent B.O.D. of less than 100 p.p.m. may be obtained when the B.O.D. concentration of the feed is from 500 to 2,000 p.p.m. Also a B.O.D. of 50 p.p.m. or less may be obtained when the B.O.D. of the feed is 1,200 p.p.m. or less. The effect of increased effluent recycle is clearly evident by comparing Figure 9 with Figure 8.

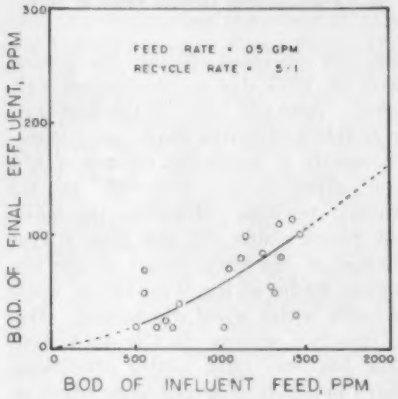

FIGURE 8.—Effluent B.O.D. at feed rate of 0.5 g.p.m. and recycle ratio of 5:1.

It should be emphasized that the effluent B.O.D. concentrations were obtained while the trickling filter pilot plant was being operated at desirable conditions. However, when the effluent recycle ratio was too low, or the pH of the feed was not in the desired 6 to 8.5 range, or the nitrogen and phosphorus nutrients were insufficient, the final effluent B.O.D. concentrations will be higher.

During the operation of the trickling filter pilot plant, the ambient temperature was recorded when B.O.D. samples were taken. The temperature varied from 30° F. to 82° F. (The unit

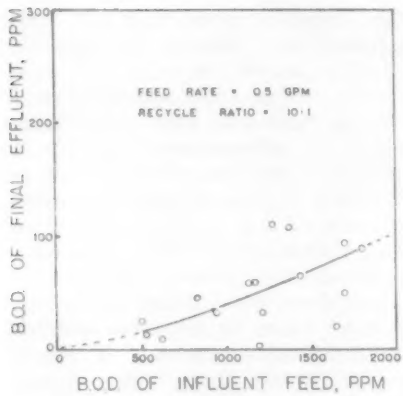

FIGURE 9.—Effluent B.O.D. at feed rate of 0.5 g.p.m. and recycle ratio of 10:1.

was not operated during the hottest part of 1953 due to mechanical failures). Actually some of the best data were obtained during the colder months; ordinarily a biological treatment system gives better removals in the warmer periods. However, the ambient temperature did not give a true picture of the temperature of the biological media as the West Sewer waste is quite warm when discharged. Due to this fact, and as the Corpus Christi area has very mild winter conditions, there probably is a minimum effect on the biological treatment method as a result of seasonal changes.

Conclusions

1. The data obtained from trickling filter pilot-plant operation suggest that the West Sewer waste lends itself well to biological treatment, under the conditions studied. It was shown that the per cent B.O.D. removed and effluent quality are most satisfactory when (a) the pH of the feed is between 6 and 8.5; (b) a constant recycle ratio of treated effluent is maintained; and (c) when a B.O.D. to nitrogen ratio of 20:1 and a B.O.D. to phosphorus ratio of 75:1 are maintained as nutrients for the microorganisms.

2. Even when the pH, recycle ratio, or nutrient feed was out of adjustment, the trickling filter system seemed to recover quite rapidly when the optimum conditions were reestablished.

3. In this study B.O.D. loadings of approximately 4 lb. of B.O.D. per day per cubic yard were obtained. The B.O.D. concentration of the influent feed varied over a range from 500 to 2,000 p.p.m. Feed rates of 0.25 and 0.5 g.p.m. were studied with an effluent recycle ratio of 5:1 being used at the lower feed rate, and 5:1 to 10:1 recycle ratios studied at the higher feed rate. The following tabulation summarizes the effluent quality (B.O.D.) obtained at the various loading conditions studied in the pilot-plant operation:

Feed Rate (g.p.m.)	Recycle Ratio	B.O.D. (p.p.m.)	
		Influent	Effluent
0.25	5:1	600 to 700	50 or less
0.25	5:1	500 to 1,500	100 or less
0.5	5:1	800 or less	50 or less
0.5	5:1	1,400 or less	100 or less
0.5	10:1	1,200 or less	50 or less
0.5	10:1	500 to 2,000	100 or less

4. Data obtained indicate that the trickling filter system could efficiently treat higher B.O.D. loadings than were obtained in this study.

SOME FACTORS IN THE LOCATION OF A NEW CHEMICAL PLANT—A PANEL DISCUSSION *

I. INTRODUCTION

By K. S. Watson

Consultant, Water Management and Waste Control, General Electric Co., Schenectady, N. Y.

In this presentation the industrial wastes panel is addressing itself to the case history of the solution of a hypothetical industrial wastes problem for a new manufacturing plant. This action is taken to help others who may be interested to understand what waste control steps are necessary in the location of an industrial facility. It is the further purpose of this problem to demonstrate the interworkings of all the people and agencies having a part in working out satisfactory waste control facilities for a proposed plant.

The hypothetical problem is as follows: The Millington Chemical Company, a large producer of chemical and pharmaceutical products, proposes to build a new plant near Newton, N. Y., a city of 30,000 people. The city is located along the Clear River, which has an average flow of 3,000 c.f.s. and an average flow for the lowest flow week each summer of 300 c.f.s. The plant will also be located along the river upstream and outside the city limits. The section of Clear River into which the plant effluent will discharge has been classified "B" by the New York Water Pollution Control Board. Fourteen miles downstream from the plant location the classification of Clear River changes to "A."

Newton takes it water supply from an upland impoundment and thus does not depend upon the river for any water. The city has a primary sewage treatment plant. All of the industrial plants located in the city are connected to this sewage treatment plant.

Since there have been numerous questions concerning the effect of this new industry on the Clear River, the staff of the Water Pollution Control Board has requested that the Millington Chemical Company have its representatives come to a meeting of the Board and explain what action it is taking to insure that the river will not be degraded. In the interest of permitting the persons most concerned in the city organizations to hear Millington's story, the city engineering organization, sewage treatment engineers, and its consulting engineers have been invited. Representatives of other industries of the city and area have also been invited. Sewage treatment personnel from some of the other sewage treatment plants up and downstream also are present. The forum audience is requested to assume, as individuals, the role in the meeting nearest those they occupy in real life. In these roles questions are invited.

Tailoring the waste treatment facilities for a new industrial plant to deliver a treated effluent which does not degrade the particular stream in question is a complex problem. The representatives on the panel will present brief statements to indicate how all the various areas play a part in developing the proper type of treatment facilities. More importantly, however, these persons are here to

* Presented at 1956 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 18–20, 1956.

answer the questions that may arise. The length of the presentations has purposely been limited to allow sufficient time for this purpose.

Acknowledgment

The moderator, who was asked to preside because the representatives of the State Water Pollution Control Board participate in the discussion, would like to express his appreciation to the members of the panel, whose diligent efforts and detailed work on this project should make it quite productive. Special thanks should also be expressed to R. W. Hess, who played a key part in conceiving National Aniline's portion of the program and coordinating it with the remainder.

II. COMPANY MANAGEMENT'S INTEREST

By C. C. Coakley

National Aniline Division, Allied Chemical and Dye Corp., Buffalo, N. Y.

Reasons for Selecting the Site

The management of this hypothetical Millington Chemical Company has selected this site at Newton, N. Y., for its new plant because of the following considerations:

1. Nearness to sources of raw materials and markets for its products.
2. A plentiful supply of good water, electricity, gas, and other utilities.
3. Waste water discharge can be controlled in such a manner as not to violate the tolerances of the receiving stream from a pollution standpoint at a cost that will not be high enough to militate against profitable operation.
4. Good transportation facilities by rail, water, and air.
5. An adequate supply of good labor which takes pride in its workmanship and in community improvements.
6. High rating of its schools, churches, recreational facilities, and stores.

Management of any new plant or of any operating plant must always consider the effect of new plant processes or modification of existing processes on pollution effect on the receiving waters. It can be safely said that all streams have a capacity to receive pollutants and eliminate the same within limits. The New York Water Pollution Control Board establishes standards for various streams in keeping with their best use. Industry has the responsibility of maintaining and not violating these established standards and, generally speaking, industry must pay the full cost of so handling its wastes as not to violate the standards established.

Products, Processes and Residuals

The products of this plant will be an organic intermediate called "Alphazo," for use in producing plastics, photographic materials, dyes, synthetic fibers, and medicinals, in this and other plants. They will be of daily use to the people of this community in making life more interesting, more comfortable, and more healthful.

Alphazo will be produced, in a unit specifically designed for this purpose, by a continuous series of condensation and a sulfonation which will be diluted with water as the final step. The Alphazo will be separated by filtration, giving a useless acid liquor waste. Of the many products which will be manufactured from this intermediate by various plants, such products as dyes, food flavor preservative intensifiers, and pharmaceuticals (including Alazoline, proven by medical science to be one of the most helpful

medicines for cardiac conditions), will be manufactured by batch operations at the Newton plant. Among the many chemicals, besides Alphazo, which will be used in these processes are phenol and cyanide. Since these substances cannot be made to react completely, there will be small amounts remaining, together with various oxidizable wastes in residual process liquors.

Equipment for these products must be designed to be much more flexible than that for Alphazo, so that each of several units can be used for more than one product, including improved or new products to meet new needs. This will result in wider variations in the nature and amounts of residuals than for Alphazo.

Working Conditions

Operations to produce these chemicals will not be backbreaking or hazardous. The latest practices in automation and other labor-saving devices, to make the work interesting and free from hazards, will be installed. The buildings and grounds will be kept clean and attractive under supervision of a good housekeeping committee, comprised of employees.

The safety of working in this plant will be further enhanced by a Safety Department, which will test equipment for safety of operation and issue instructions for safe practice. It will be enhanced still further by a special Safety Board of highly trained personnel with long experience in research, operating and engineering, who will not allow any process to be operated without its approval, and by several safety committees at all levels of employees who will make periodic inspections and recommendations on the safety of working conditions.

The buildings will be of the latest design for good ventilation, light, roominess and accessibility to working areas. The buildings will be widely spaced and the surrounding areas will be attractively landscaped.

Value of Plant to Community

This plant will employ 1,200 people, calling for a large variety of skills as represented by process operators, mechanics, pipefitters, truck drivers, foremen, clerks, typists, comptometer operators, supervisors, chemists and engineers. It will bring money into the community to meet this payroll, to pay company taxes for education and other community improvements, and to stimulate business and community activities generally.

The company has a reputation for wastes control, good labor relations, generous contributions to community funds, and of good public relations generally.

Waste Control

The management of this plant will take the initial steps required to meet the Water Pollution Control Board's quality requirements for Clear River. This will be accomplished by the adoption of processes which have been developed to give the minimum amounts of objectionable wastes. Some which cannot be avoided will be recovered and used, hauled to the dumps, burned, or destroyed chemically or biochemically.

These operations will be an integral part of and will be given the same attention as production operations by all personnel involved. They are written into the standard processes for each product, from which no departure is allowed except to make improvements.

If production facilities are expanded, additional wastes produced will be handled in the same manner.

If production of new products is undertaken, waste control will start in the research laboratory, during development of production processes, on minimizing the amount of objection-

able wastes and development of treatment methods for those which cannot be avoided. In cooperation with research and development chemists or other specialists, engineers will design and install necessary equipment.

No new process, equipment installation, or alteration will be allowed to operate until approved by pollution control specialists.

A special laboratory, with specialized equipment and manned with experts in industrial wastes and water pollution, will be provided. This laboratory will make tests on effluent and receiving waters to make certain that water quality requirements are being met. It will also do research work on methods of treating wastes and on analyses which do not come within the knowledge and experience of personnel in the research and analytical laboratories.

All personnel involved in this activity are encouraged, at company expense, to attend meetings of technical societies dealing with the problem. The plant library will be supplied with periodicals and books by authorities in this field.

The plant will work in close cooperation with water pollution control agencies. It will offer its assistance in taking samples, measuring volume, and testing effluent. Conferences will be held with and reports made to these agencies on request.

Special accounts will be allocated to the costs of treating wastes, technical controls, research on the problems, and supervision of the program. It is recognized that prevention of pollution costs money.

The entire program will be under the direct supervision of the company's industrial wastes coordinator.

III. STATE CONTROL AUTHORITY'S INTEREST

By W. H. Larkin

Chief Engineer, Water Pollution Control Section, New York State Department of Health, Albany, N. Y.

New York State's water pollution control law charges the Water Pollution Control Board with the responsibility of protecting the waters of the state for the benefit of all the people of the state. The operation of this program is a big job. Interest and support of the people of the state are necessary for the success of any such program. This program has had, and does have, the support of all interested groups, including lay organizations, municipalities, and industries.

This discussion of the proposed location of a new industry in the community of Newton offers an excellent opportunity to tell briefly how the water pollution control law operates for the protection of the river, in behalf of the townspeople and in behalf of their neighbors.

It would be worthwhile first to give a brief outline of the salient provisions of the law and of its operation, and then to discuss the handling of the problem of sewage and waste disposal from the proposed plant.

State Law

The law is considered to be a comprehensive type. It states the public policy to be "to maintain reasonable standards of purity of the waters of the state consistent with public health and public enjoyment thereof, the propagation and protection of fish and wildlife, including birds, mammals and other terrestrial and aquatic life, and the industrial development of the state, and to that end require the use of all known available and reasonable methods to prevent and control the

pollution of the waters of the state of New York."

It is also stated in the law that the purpose is to safeguard the waters from pollution by (a) prohibiting any new pollution and (b) abating existing pollution. Pollution may be defined as any discharge of waste which results in the contravention of standards adopted for the receiving waters.

Classification

The law further provides for grouping the waters in classes with appropriate quality standards, and under authority of the law the Water Pollution Control Board has adopted a system of "rules and classifications and standards" for state-wide application.

In this classification system, seven different classes, with appropriate quality standards, have been adopted for fresh surface waters. These classes include:

Class AA, for which the best usage is as a source of water supply for drinking, culinary or food processing purposes and any other usages—it being expected that water taken from this class need be given only approved disinfection treatment to make it satisfactory for use as drinking water.

Class A, for which the best usage is also as a source of water supply for drinking, culinary or food processing purposes and any other usages—it being expected that a water supply taken from this class would be subjected to approved complete treatment equal to coagulation, sedimentation, filtration and disinfection.

Class B, for which the best usage is bathing and any other usages, except as source of water supply for drinking, culinary or food processing purposes. It should be understood that if any specific water is needed as a source of water supply, it would have to be placed in Class AA or A, rather than in Class B or any lower class.

Class C, for which the best usage is fishing and any other usages except those which would require a higher quality standard.

Class D, for which the best usage is agricultural or as a source of industrial cooling or process water.

Class E, for which the best usage is sewage or industrial wastes disposal and transportation.

Class F, for which the only usage would be for sewage or industrial wastes disposal.

Procedures

Before waters of the state can be classified certain procedures are required, some of which are admittedly detailed and time consuming. These include:

1. Making of an engineering survey giving consideration to the hydrological features of the waters, land uses, present and foreseeable water uses, and present defilement.
2. The preparation and publication of a report covering such study.
3. The conduct of a public hearing, giving all interested parties a chance to express themselves in relation to proposed classification.
4. Adoption of the official classification by the Water Pollution Control Board, taking into consideration the results of the survey and any recommendations which may have been made at the hearing.

Following the official classification of the waters, it is necessary to prepare a comprehensive abatement plan which deals with all important sources of pollution, and which plan is adopted by the Board. With the comprehensive abatement plan, the Board is then in a position to take action toward securing the correction of any existing violation.

In accordance with the policy outlined in the law and adopted by the Board, attempts are first made to secure correction through cooperative means. Should all reasonable attempts at cooperation fail, it then becomes necessary to resort to the legal provisions of the law. Fortunately, a very large percentage of the municipalities, industries, etc., responsible for violations, desire to cooperate with the Board and are willing to agree to reasonable programs leading to the correction of the situation.

The Millington Situation

Up to the present, waters covering approximately one-half of the state have been classified, including the Clear River and its tributaries. The survey of this river was made, the report has been published, and the official hearing was held several months ago. The results of the report and all presentations made at the hearing indicated the proper classification of the river in the vicinity of Newton to be "B," the best usage for which is bathing. As is known, that city gets its water supply from upland sources and there appears to be no apparent need to resort to the river for its water supply. However, one of the municipalities downstream does have need to use the river as its source of water supply. Therefore, as indicated by Mr. Watson, a section of the river beginning about 14 miles downstream from the city of Newton has been classified as "A."

The quality standards for waters in Class B include the following:

1. Floating solids, settleable solids, sludge deposits—"None which are readily visible and attributable to sewage, industrial wastes, or other wastes, or which deleteriously increase the amounts of these constituents in receiving waters. . . ."

2. Sewage and waste effluents—"None which are not effectively disinfected."

3. pH—"Range between 6.5 and 8.5."

4. Dissolved oxygen—". . . not less than 4.0 p.p.m."

5. Toxic wastes, oil, deleterious substances, colored or other wastes or heated liquids—"None alone or in combination with other substances or wastes in sufficient amounts or such temperatures as to be injurious to fish life, make the waters unsafe or unsuitable for bathing. . . ."

The quality standards for Class A waters are similar to those just outlined for Class B, except that in addition there is a prohibition against the discharge of odor-producing substances or phenolic compounds which might interfere with the use of water for drinking and culinary purposes.

As mentioned previously, the water pollution control law prohibits the establishment of any new outlet for discharge of sewage or industrial wastes except under permit from the Water Pollution Control Board. It would have been necessary, therefore, for the Millington Company to have secured a permit for the discharge of its sewage or waste effluents, even though the waters of Clear River had not been previously classified. Since these waters have been classified, the proposal of the company was reviewed with a definite knowledge of the official quality standards for the receiving waters.

In its very early stage of consideration of Newton for the location of its plant, representatives of the Millington Company conferred with representatives of the Water Pollution Control Board in relation to its sewage and waste disposal problem. Although the Board was in possession of some data concerning stream flows and the quality of the river water, which information had been adequate for the establishment of the classification, it was considered desirable that some addi-

tional data be secured. In accordance with the Board's request, the industry gave its fullest cooperation in the making of additional surveys. With this additional information, the report and preliminary plans of the company outlining the quantity and character of its wastes and its proposed treatment, it was determined that with satisfactory operation of the treatment, the discharge would not result in contravention of the "B" standards for the river. In considering the company's proposal, attention also was given to the possibility of discharge of phenolic compounds or other taste-producing substances which might result in contravention of the "A" standards by the time the waters reach the section of the river classified as "A", 14 miles below Newton. It appears reasonably certain that these standards will not be violated.

It is expected that with the construction and operation of the Millington plant, and its sewage and waste treatment facilities, adequate controls over operation will be set up and reports will be made available for review by representatives of the Water Pollution Control Board.

Some detailed information concerning the proposed operations of the industry and its sewage and waste treatment plant will be given by representatives of the company.

IV. INDUSTRIAL SEWAGE SPECIALIST'S INTEREST

By W. M. Steinfeldt

Eastman Kodak Company, Rochester, N. Y.

An attempt will be made to explain briefly how Millington plans to dispose of its industrial sewage without offense and without pollution.

First, it must be emphasized that the liquid discharge is industrial sewage and not industrial waste. To industry, waste means a careless, heedless discarding of materials. Millington does not throw materials away, or more specifically, down the sewer, needlessly or carelessly. The company would not last long in a highly competitive business if it did. When pots and pans are washed at the kitchen sink, the wash water carries away the residues from the meats, vegetables and whatever else has been on the menu. The result is one component of domestic sewage.

When, in the company's plants, a reactor is cleaned (the equivalent of the domestic pressure cooker), the result is industrial sewage. Manufacturing personnel haven't been at all careless in that cleanup, for the reactor has been designed to reduce trapping of the chemical "soups" to a minimum, and before it was washed, it was rinsed once with a solvent to carry away as much of the "soup" as possible back into the process. But inevitably, no matter how well the good housekeeping procedures are carried out, some industrial sewage, not the result of waste, must be run off to a sewer and a treatment plant.

Secondly, the concept of pollution should be briefly reviewed. Pollution may be most simply defined as "too much." This can be illustrated further. Probably no word in the English language has more slang equivalents than "intoxication." The use of "polluted" to mean "intoxicated" is an excellent illustration of why pollution is "too much." A wee dram is not harmful; indeed, alcohol is used in many medicinal preparations. Several of these wee drams, however, are too much and the result is "pollution."

Exactly the same situation occurs on the Clear River and on probably every

other river in the country. A small amount of organic material, either domestic sewage or industrial sewage, will not hurt the river, and in fact may stimulate aquatic life by furnishing an ample food supply for a larger bacteria population, which in turn furnishes food for higher animal forms and eventually increases the fish population. But more sewage begins to hurt the river and finally the overdose causes pollution. It is the intent of the Millington Company to carry on its manufacturing operations, and to discharge its industrial sewage, treated where necessary, to the river in such a manner that the river remains a clean and healthy stream.

How Pollution Will Be Prevented

Mr. Coakley has already described how Alphazo will be made and how it will be used in the production of several products here and elsewhere.

All of the several steps in the manufacture of Alphazo will be carried on continuously; the manufacturing equipment is specifically designed for this process and this product. This means that full advantage is being taken of every possible way of recycling unreacted materials, and that each piece of equipment and each step in the process can be designed for optimum efficiency.

Figure 1 shows the general flow sheet of the process. This flow diagram appears complex, but then the process itself is complex. No attempt will be made to explain the process in detail, but only to point out some of the ways the Alphazo process has been designed to keep industrial sewage to a minimum, as follows:

1. Cooling towers are used, a rather common means of reducing the volume of cooling water discharged to the river, and of reducing thermal river pollution.

2. A scrubber is used to remove phenol from a vapor stream and to recover the phenol. It should be noted

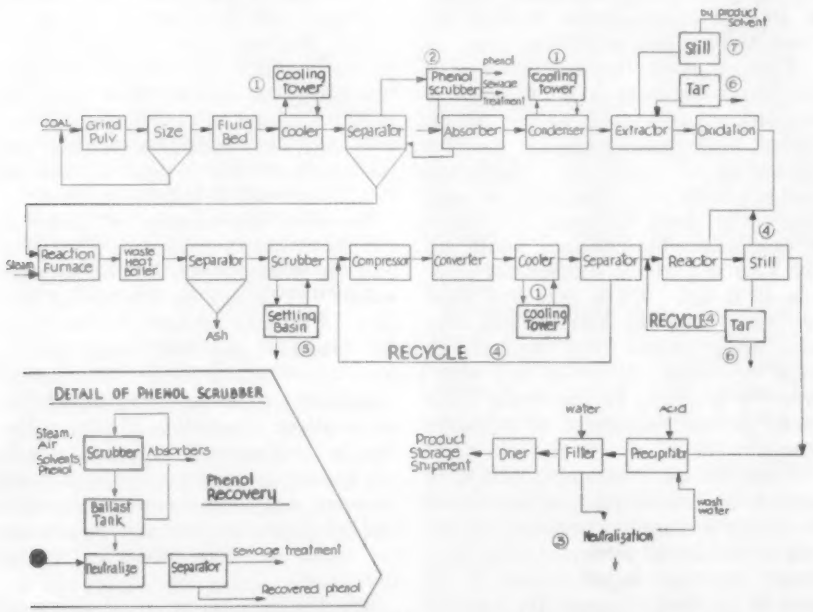

FIGURE 1.—Flow sheet of the chemical manufacturing process for Alphazo.

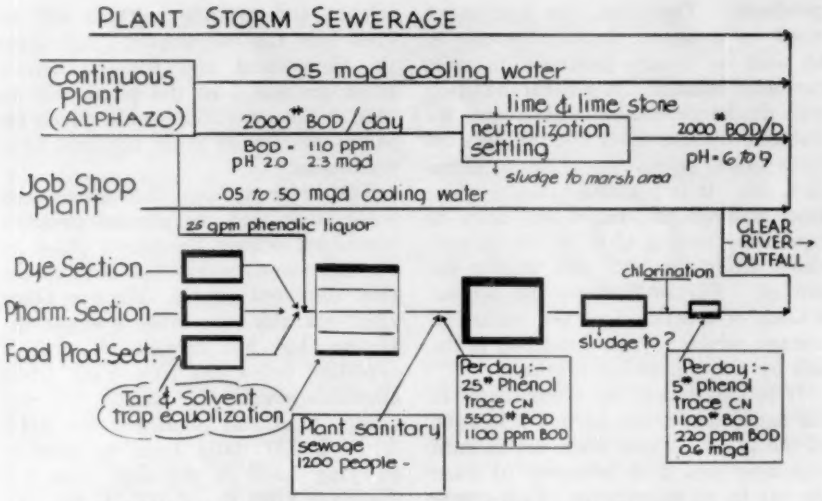

FIGURE 2.—Flow diagram of the industrial sewage treatment plant.*

that although this scrubber is 99 per cent effective, 1 per cent of phenol still will remain in the water and this phenol stream will be discharged to the industrial sewage treatment plant.

3. Neutralization of the acid effluents is called for. In the final step of the Alphazo process, the Alphazo is precipitated with sulfuric acid, which must then be washed from the Alphazo. As a result, there is produced 2.3 m.g.d. of industrial sewage with a B.O.D. of 2,000 lb. per day and a pH of 2. This will be treated in a neutralizing basin to raise the pH to a minimum of 6.0 with limestone and lime. A sludge filter cake, from the settling of the $CaSO_4$ produced in neutralizing, will be disposed in a sanitary fill in the marshy area north of the plant along the river. Note that it is planned to recycle some of the neutralized effluent back into the process, in order to reduce the volume of discharge to the 2.3-m.g.d. flow mentioned previously.

4. Recycling steps in the process are designed to convert the materials completely and to have no waste.

5. Another re-use of water in a scrubber removes solids and acid-forming gases. The solids are settled and discharged as a sludge; lime is added to neutralize the water for re-use in the scrubber and to remove any acidity in the sludge.

6. Tars are separated from product streams, and collected for burning in the incinerator.

7. Recovery of solvent, low in concentration, is by distillation. It will cost $0.08 per pound to concentrate this solvent to a marketable concentration, although the present market price is only $0.075 per pound. The company prefers incurring this cost to flushing the product down the sewer.

In the second part of the plant Alphazo will be used as a raw material for dyes, for Alphazoline, and for the food flavor preservative intensifier. These products will not be made continuously as Alphazo will be, but will be made in batches for several days out of a month to build up a sufficient inventory or to meet customer orders. However, the company's experience is that products such as these often are superseded by better

* Plant sanitary sewage estimated at 48,000 g.p.d.

products. Therefore, the equipment must be designed flexibly enough to be able to change processes to meet customer demand. In general the plant will discharge cooling water, and industrial sewage from the washing of filter cakes, equipment cleanup, filtration, etc. It is planned to carry these first through tar traps and then to equalizing basins, after which an activated sludge process will purify the sewage. Figure 2 shows the general scheme of treatment of the industrial sewage, which will be described in detail by the consulting engineer.

It is found that tar accumulates in the tar traps in the normal operation of the plant. These traps are cleaned regularly and it is intended to burn the tar in an incinerator. This course is preferred to burying the tar, because this method permanently disposes of all tar. The consulting engineers are being requested to design an oil-fired rotating horizontal kiln for this incinerator, so as to handle, in addition to the tars, heavy residues from the reactors, filter press residues, and combustible trash from the plant. It is also planned to accumulate the unreacted cyanide, from one of the dye processes, in a solvent mixture. This solvent and cyanide mixture will be fired into the incinerator. Ash from the incinerator and non-combustible trash generated in the plant will be sent to the same dump area which receives the sludge from the acid neutralization.

The river studies that have been made show that the present primary municipal sewage treatment plant in Newton causes some depletion of the river dissolved oxygen. The new plant upstream also will cause a slight depletion, but not enough to cause a depletion below the New York State allowable standards. Briefly, the city sewage treatment plant removes 2,500 lb. of B.O.D. daily from an influent carrying 7,500 lb. per day, thus discharging 5,000 lb. of B.O.D. per day to the stream. Figure 2 shows that after treatment of the Alphazo waste 2,000 lb. of oxygen demand would be discharged to the river and the activated sludge treatment plant would discharge 1,100 lb. of oxygen demand per day. In all, this amounts to 3,300 lb. per day, in a total flow of nearly 4 m.g.d. Figure 3 shows why it is felt that the plant industrial sewage discharges will not impair the Clear River. The dashed black line

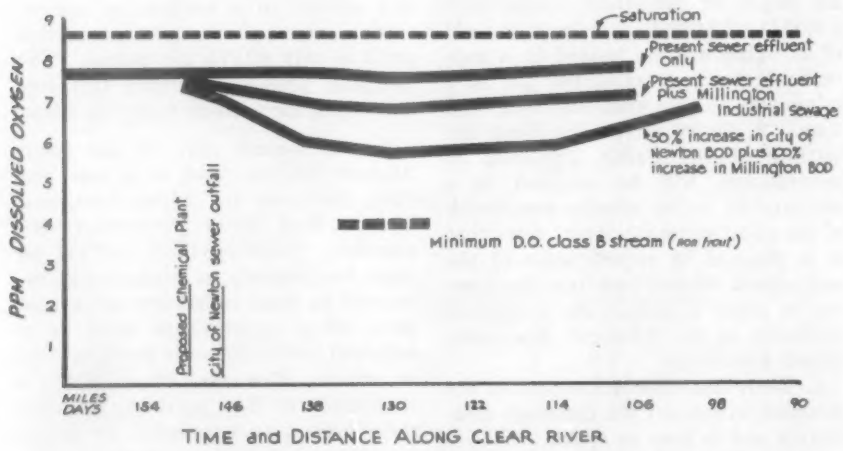

FIGURE 3.—Calculated dissolved oxygen profile for Clear River.

TABLE I.—Data for Application of Oxygen Sag Curve Equation

Item	Value	Source
Minimum stream flow	300 c.f.s.	USGS records
Time of passage and stream velocity	0.5 f.p.s.	Stream cross-sections, $Q = AV$
Deoxygenation coefficient, K_1	0.10	Laboratory studies
Reaeration coefficient, K_2	0.25	Assumed data fit data from river tests
Initial deficit, D_i	1.0	River tests
Ultimate demand, La	—	Calculated from 5-day demand, based on $K = 0.10$
Maximum temperature	75° F.	10-year maximum, steam power plant data

shows the maximum or saturation value for dissolved oxygen in the stream at maximum temperatures, and the top solid line shows the dissolved oxygen in the river during August 1955. The slight drop in D.O. at the point 16 miles downstream from Newton is only a few tenths of a part per million and is the result of the soluble B.O.D. in the city of Newton treatment plant effluent. The Clear River today is a healthy stream as far as dissolved oxygen is concerned.

After the Millington plant is constructed and its treated industrial sewage is discharged to the river, it is calculated that the D.O. profile will be as shown by the second solid line. This still represents a healthy stream. Let's look into the future a bit. At this time, there is every indication of an expanding economy and every reason to expect to increase the industry's capacity. The third solid line shows the D.O. profile in the Clear River with a 50 per cent increase in B.O.D. from the Newton treatment plant and a 100 per cent increase in the B.O.D. from the Millington plant. The lowest line shows the minimum D.O. (4 p.p.m.) for Class B non-trout waters as Mr. Larkin has already explained. Thus, even with future increases the Clear River should remain a healthy stream. One point that should be called to attention is that the sewer system in Newton is largely of the so-called combined type. Under certain cases of excessive rainfall these sewers overflow into the river, imposing a very high pollution load on the stream.

Basically, the analysis from which Figure 3 was developed used the classic oxygen sag curve equation of Streeter and Phelps. From a sampling of the Clear River and from the Water Pollution Control Section's data, this equation fairly well measures the action of the organic wastes on the river, particularly since there is no appreciable load from sludge deposits. An assumed reaeration coefficient of 0.25 fits the data fairly well. Table I gives the source of the other remaining data for the application of the oxygen sag curve equation.

In summary, the new industrial plant will not discharge any suspended solids to the stream, and phenol concentrations will be kept within the 5-p.p.b. concentration required by the state standards. The traces of cyanide in the effluent will be so low that present analytical methods are not able to determine them quantitatively. The B.O.D. will not deplete the dissolved oxygen in the river. Thus there need be no apprehension about Millington's industrial sewage polluting the Clear River.

V. THE CONSULTING SANITARY ENGINEER

By John J. Baffa

Consulting Engineer, New York, N. Y.

Engineering design for the translation of the proposed treatment plant into reality is the next major step along the Millington Company's road to production of Alphazo after the industrial waste specialist has completed his work. To accomplish this step, it is necessary to prepare plans and specifications which will enable the construction of operable treatment facilities. The procedures and factors relative to the engineering work are hereinafter described in narrative fashion as comprising part of the case history of the Millington project.

The circumstances surrounding the engineering design for Millington are believed to be common to many industrial waste water disposal projects involving the construction of new industrial plants. The procedures employed by Millington in approaching the engineering considerations are those which represent a desirable approach to such matters.

Before proceeding with the description of the engineering work, it is believed pertinent to explain that Millington is a large company and employs a full-time sanitary engineer industrial waste specialist with sufficient assistants to carry the solution of the problem up to the point indicated by Mr. Steinfeldt. Industries without a waste water disposal staff would require the consulting sanitary engineer to do the work which in the case of Millington was performed by the industrial waste specialist. The phase of the work which might involve reduction of waste load as related to the chemical or biological or production aspects of the manufacturing process, or which might involve special research for the determination of the treatment process, could be directed by or coordinated by the consulting sanitary engineer in cooperation with the plant chemical engineer or a sanitary chemist or biologist or process research firm. In some cases such services might be handled separately by the particular experts most qualified.

Engineering design and the preparation of plans and specifications are also performed by the engineering departments of large industrial organizations. In the case of Millington, the engineering forces did not have the inclination, the time, or the know-how to proceed with the engineering work involved, so that consulting sanitary engineering services were in order.

To proceed with the case history of the Millington project, the following facts are discussed in the order listed:

1. What was the scope of the engineering work?
2. How much time was allowed for engineering work?
3. How was the consulting sanitary engineer chosen?
4. What were the design requirements of the proposed installations?
5. How were the design problems solved?

Scope of Engineering Work

The scope of the engineering work was set up so that the consulting sanitary engineer was required to do the following:

1. Prepare complete and detailed plans and specifications for the treatment facilities in accord with the design data determined by the Millington waste specialist.
2. Confer with the industrial waste specialist and plant engineers as required for coordination of the manufacturing process, waste water treatment, and site planning.

3. Make alternate layouts and estimates for discussion and final decision.

4. Coordinate the work with the State Department of Health so that necessary permits can be obtained.

5. Aid the owner in selecting a contractor to do the construction work.

6. Provide consulting services during construction to the owner's full-time construction engineering department.

7. Provide operating instructions for the use of operating personnel.

8. Provide record drawings at the end of the construction period.

9. Assist in the initial operation of the plant.

Time for Engineering Work

Eighteen months was the time allowed by Millington for engineering and construction. Six months of this time was allowed for the engineering and securing of permits. The time was chosen to coincide with completion of the new manufacturing facilities. The plant had to be put in production on time in order to beat the competition to the market, obtain product revenue on schedule, limit investment money tied up in uncompleted facilities, and take due account of the uptrend of construction costs. All these factors were evaluated by Millington at 5 per cent of total plant investment per month of delay beyond the time allotment. However, due consideration was given to the fact that inadequate time for engineering and construction represented false economy. The times chosen were believed to be minimum practical values.

Choice of Consulting Engineer

Three consulting sanitary engineering firms known to be active in the industrial waste water field were called in, one at a time. The engineers were advised that the industrial waste specialist had analyzed and defined the problem and that the waste water volume had been reduced to an absolute minimum, as had been the waste water contaminants. The residues now proposed to be carried by the waste water were not recoverable by any known method, were not salable, and were not of value to anyone. Therefore, engineering services were required to design a treatment plant of the type devised by the industrial waste specialist. The scope of the work was described to each engineering representative and he was asked if he were interested and his qualifications were discussed.

The choice of a consulting sanitary engineer was based on the following factors:

1. Activity in the industrial waste water field.

2. Extent of experience with the design and construction of waste water treatment facilities, with particular reference to type of treatment plant involved.

3. Professional background in sanitary engineering.

4. Immediate availability and likelihood of meeting the time schedule.

One engineering firm was engaged. The cost of engineering services was negotiated after the firm had been engaged. Otherwise stated, the cost of engineering services had nothing to do with the choice of engineer.

Design Requirements

The engineering design had to provide for the design data determined by the industrial waste specialist. The following data had been determined:

1. Total flows and flow variations.

2. Waste quality and quality variations.

3. Type of treatment necessary to meet stream requirements.

4. Amount of lime required for neutralization, reaction time required, and volume of sludge produced.

5. Time required for equalization of flow and quality.

6. Aeration time, air requirements, and return sludge requirements.
7. Settling time, volume of sludge, and sludge moisture.
8. Sludge dewatering characteristics.
9. Chlorine demand.

Additional design requirements were as follows:

1. Since no actual waste sampling had been possible because this was the first "Alphazo" plant to be built, it was required that a maximum of flexibility be allowed for aeration, return sludge, and chemical feed facilities. In these respects, the operation of the completed plant would be experimental to some degree.

2. Alphazo might sell very well. Market research indicated a huge potential market and it would probably be necessary to double the treatment facilities within a few years.

3. If the plant were eventually enlarged, it would have to be operated 24 hr. per day while it was being enlarged.

4. Millington's cost accounting was based upon the "Alphazo" plant paying out in three years from production revenue. Accordingly, capital cost had to be kept to a minimum.

5. Current research on Alphazo might result in different waste water contaminants within a few years. Accordingly, capital costs had to be kept to a minimum in view of possible future revamping facilities. This was also another reason for building in as much flexibility as possible.

6. Competitive research was active, so that cost of the product would have to be kept down. Therefore, operating costs would have to be kept to an absolute minimum compatible with passable performance.

It was also pointed out that Millington would continue research on methods of greater recovery of waste water contaminants and means of reducing waste volume.

Engineering Design

Thus, as is common to most industrial waste water problems, the impermanence resulting from the concepts of expendibility and continuing change had to be recognized in making engineering designs. These concepts allow wider latitude in choice of materials and layout of facilities and in the provision of operating comforts than would be the case with structures and facilities designed for permanence and relatively stable circumstances. However, the production of a good effluent was considered of paramount importance.

Space will not permit going into all of the technical details for the treatment plant design. Some of the highlights only will be covered. Flexibility was achieved by the use of multiple units, variable-speed devices, and piping arrangements. Automation was provided for pH control and for flow metering. The pH control was impossible manually and the saving in lime and sludge handling resulting from automatic control would more than pay for the automatic equipment and its maintenance. Recording meters for waste flows and return sludge were considered invaluable because of the records and facilitation of operation thus provided. The rest of the plant was to be operated entirely manually.

To provide for future possible doubling of capacity, the site arrangement was laid out to allow for duplication of all units. Key fittings and valves in pipelines were arranged to allow for the future connection of parallel pipelines without flow interruption. The aeration and neutralization basins were arranged with construction joints so that additional basins could be attached in the future within a minimum of space; flumes were arranged so that future connections could be made without flow interruption. Similar provisions were made for all pumps and the vacuum filter. The provisions

for future expansion were possible at a very slight increase in construction cost.

To keep capital investment to a minimum in keeping with the fast write-off requirements, the plant buildings were designed purely on a functional basis and industrial-type prefabricated shelters were used wherever possible. No laboratory or office was provided at the waste treatment works, as such facilities were available in the manufacturing plant buildings. In the layout of piping and valves, process efficiency and operating efficiency were given major weight and the operator's comfort was generally considered secondary. However, operator safety was stressed and all the safety requirements of the law were complied with.

Permits

The local district office of the State Department of Health was kept advised of progress on the design drawings and from time to time preliminary discussions were held. Upon completion of the drawings and specifications to the satisfaction of the industrial waste specialist, process experts, plant engineering forces, and the district engineer of the State Department of Health, an application in final form was submitted to the Water Pollution Control Board by the owner to obtain a permit to discharge effluent into the waters of the state. Upon final review by the industrial waste specialists of the State Department of Health, this permit was granted to Millington.

Construction Contract

The project was then ready for obtaining contractors' estimates and choosing a contractor. Consideration was given to four types of construction contracts, as follows:

1. Lump sum.
2. Cost plus.
3. Unit price.
4. Guaranteed maximum, with division of savings.

The type believed best suited to all the conditions involved in this particular instance was the guaranteed maximum with division of savings contract. The basis for this choice was that the drawings and specifications were sufficiently detailed to permit estimating a maximum cost and the division of savings feature provided incentive to the contractor to do the work as economically as possible.

Three selected and interested contractors were invited to make estimates and submit qualifications.

The contractor was chosen on the basis of estimated price, experience and performance with similar construction, adequacy of financial assets and organization, and availability to complete the work in the required time. The project then entered the construction phase.

VI. THE CONTRACTOR

By H. E. Lauman

New York, N. Y.

Experience

An experienced contractor is important in any type of construction, but in industrial waste treatment an experienced contractor is even more important. The designing engineer issues specifications and plans, usually quite similar in detail to plans customarily issued for general construction work. From these plans and specifications the contractor must visualize the completed structure and its function and purposes.

In making up his bid for the work,

the contractor cannot rely entirely on the drawn lines of a cold-blooded blueprint, nor the literal writings in the specifications. His organization must have the experience and know-how to "picture" the completed installations and follow the treatment procedure from the entry of the waste to the outfall. This will enable the bidding contractor to render an intelligent bid and, if he is awarded the contract, it will permit him and his organization to do a successful job for all concerned.

The industrial waste disposal program and the construction for the required facilities are relatively new by comparison with other conventional construction methods. There are comparatively few contractors that have the experienced technical force, or know-how, to qualify in all respects for the construction of industrial waste disposal systems.

In areas where experienced contractors for this type of work do not exist, contractors with experience in kindred industries and contractors with qualified engineering personnel can adapt themselves for this type of work.

Installations in existing operating plants offer unique problems to the designing engineer and ultimately to the contractor. The major problem is to fit the designed system into the existing conditions. In existing installations of this type, the usual problem is to separate the various wastes accumulated from the various sources and bring the wastes that require special treatment to a common point for such treatment. Flow lines are usually underground or below concrete operating floors. Existing plans and records of the position, elevation, size and condition of such flow lines are seldom available. If they are available, they often are not reliable.

The designing engineer cannot be expected to describe all these conditions accurately in any great detail. Again, it requires a contractor of experience with an organization that can visualize and comprehend these situations in order to construct a system that will function as intended.

Drawings and Specifications

How detailed should the engineer's drawings be and also the specifications?

The engineer's drawings and specifications should be in sufficient detail to adequately describe the system and its intent. Pipe sizes and conductors should be properly indicated. Wherever possible, the job conditions should be adequately described so that the contractor, both in his bidding and in his construction work, can interpret from the prints and the specifications a reliable and clear picture of what to expect. Elevations and gradients of pipelines should be accurate and reliable to prevent serious obstructions in construction.

The intent of the system, the flow capacity at various points, the nature of the material, its behavior, its various temperatures, its corrosiveness, dangers of gas entrapment, etc., should be designated to guide the contractor in the selection of materials, hazards of construction, etc.

In many instances an experienced contractor can be a great help in handling unusual conditions that are not anticipated or covered in the specifications. It is worth repeating: it requires close cooperation between a designing engineer and the contractor to construct a plant that will serve the purpose intended. The specifications and plans should be written in the language of the 'trade' and in sufficient detail to avoid later misunderstandings.

Bidding Procedures

What procedures should be followed in taking bids?

Bids for waste disposal systems should be requested from a predetermined list of qualified bidders. The method or means of procuring a list

of qualified bidders will vary territorially. In areas where a certain number of installations have been made, of the type required, there should be no difficulty in obtaining qualified bidders. In areas where no previous installations of the required type have been made, the owner and engineer may be required to interview contractors in kindred lines and determine their suitability.

For intricate installations, of major proportions and contract value, an experienced contractor, although located at a distant point, can usually compete with local contractors both in initial cost and in more efficient construction. It is best to receive bids on a more or less informal basis, by invitation from a preselected list of contractors. Three or four bidders should be ample.

A good procedure is to select one or two of the bidders that seem most favorable and have a formal meeting and discuss with them the intended work, its coordination with other work, etc. In this way, the owner and the engineer can determine the capabilities and status of the bidder and his organization to complete the work in the manner intended. Quite often, there may be distinct advantages to the owner to engage a contractor other than the apparent "low bidder."

Contract Extras

When does a contractor expect "extras"?

The question of "extras" is a touchy one with all owners, engineers, and contractors. A good proportion of the extras are brought about by misunderstandings of plans and specifications, lack of coordination between other trades, or progress of the job. In new construction, where all factors are known beforehand, there should be practically no reason for extras, unless major material changes in the construction are made after the construction has been entered into.

In waste disposal plants installed in existing operating plants, claims for extras can easily be justified, due to encountering conditions unknown to either the engineer or the contractor prior to the start of the work. Extras will more often occur in contracts where the contractor has had limited experience in the type of work for which he has contracted.

Adopting the procedure outlined in the previous paragraph—particularly in the prequalification of the bidders, interviews with the bidders, and negotiations on any points of misunderstanding in the specifications or plans—prior to the issuance of the contract, will go a long way towards reducing claims of extras during the construction of the job. On installations in existing industrial plants, the treatment system must be fitted into and around the existing fixtures and the question of extras is doubly touchy.

Specifications and plans cannot be sufficiently detailed to cover the bidder on obstacles that may be encountered when working below a factory floor or below the ground generally. Plans of existing piping systems are none too reliable. These plans are usually the intent of the engineer or architect that specified the original installation. Very seldom are they corrected as to relocation of piping, etc., during the installation or construction period. When there is a question of elevation of certain utilities, and where space is limited and obstacles occur, a change in elevation of the subsequent piping may upset the equilibrium of a system, particularly where space and slopes are predetermined with very little marginal leeway. On new construction, where waste disposal systems are installed concurrently with other planned utilities, practically all these obstacles or questions of extras are eliminated.

Again, it is the question of "know-how" of the contractor, his close cooperation with the designing engineer,

and his coordination with other trades, that will eliminate the touchy problem of claims for extras.

Work Guarantees

How do contractors feel about guaranteeing their work for one year?

Any reputable contractor that understands the functions and purposes of the installation that he is constructing, should not hesitate to guarantee the mechanical features of his work for a period of one year. If he is fully apprised of the type of liquids and residuals to be handled, their aggressiveness, or other behaviors, he shares a certain responsibility with the designing engineer for the proper function of the system.

He should not be held responsible for the proper operation of the system, its maintenance, or conditions that may arise on a job that were not anticipated by him or the engineer during the construction period.

This refers principally to the possibility of a major change in the nature of the wastes to be treated that may affect the equipment or the piping because of the gathering of residuals at points that may clog the system or interfere with the flow cycle.

VII. THE OPERATOR

By Thomas V. Kenny

Sanitary Engineer, Lederle Laboratory Division, American Cyanamid Company, Pearl River, N. Y.

It is apparent from the previous talks that the Millington Chemical Company has spared no expense in designing the most up-to-date waste treatment plant possible. However, it is not enough to incorporate the latest improvements in the design of of the plant, and the company feels that any process, no matter how well it may be laid out on paper, is no better than the capability of the operating personnel. In this regard, it is felt that the operator can "make" or "break" the plant, regardless of how well it is designed.

With this in mind and being aware of the complexity and sensitivity of the activated sludge process, which it is proposed to use, it has been decided to hire a graduate sanitary engineer and train him for at least a year at one of the company's existing treatment plants handling a similar waste problem. During this year he will become thoroughly versed in the operation of an activated sludge plant, including selecting and training the qualified personnel required to help him run the plant at peak efficiency. He will come in contact with the specific type of equipment used, including the operation of a vacuum filter, and will familiarize himself with the number and type of samples and records necessary to properly gauge the performance of the treatment units.

In addition to the actual operation of the treatment plant, the operator will be responsible for setting up and carrying out a program of waste elimination and utilization at the source, as mentioned previously by Mr. Steinfeldt. This point cannot be overemphasized. This program will play an extremely important role in the successful operation of the treatment units.

Since this treatment plant will contain the latest in automatic controls and recording equipment, it will require only a two-shift operation with a five-day work week. It is intended to staff the plant with the following

trained personnel besides the operator:

(a) an assistant operator,
(b) two vacuum filter operators,
(c) two plant helpers,
(d) a laboratory technician.

In recognition of the importance of maintaining a satisfactory effluent in order to protect the Clear River from degradation, management has instructed that a system be set up by means of which constant surveillance can be maintained on the strength and composition of the waste as it passes through the plant. To comply with this request, it is planned to set up a series of automatic sampling devices at the crucial points in the treatment system. Most sanitary engineers are familiar with the inadequacy of the B.O.D. test, which requires the lapse of five days to obtain a result. Nevertheless, it is the recognized criterion for determining the effect of any treatment plant effluent on the stream into which it is emptied. Therefore, the C.O.D. test will be used in conjunction with the B.O.D. test for a quick rough estimate on the performance of the treatment plant.

These tests, together with suspended solids (both volatile and ash), dissolved oxygen, organic nitrogen, ammonia, nitrites, nitrates, and settling properties of the activated sludge, will be run by the laboratory technician and utilized by the operator in gauging the performance of the treatment plant. One of the company's existing laboratories, which fortunately is adjacent to the proposed plant site, will be completely equipped with a refrigerator, a 20° C. incubator, Kjeldahl stills for the nitrogen and ammonia tests, reflux apparatus for the C.O.D. tests, Gooch crucibles together with a drying oven and furnace for the suspended solids, 1-l. cones for the settling solids tests, an analytical balance, and a microscope for a periodic visual check on the condition of the floc in the aeration tank. Included also will be the necessary apparatus for checking on phenol and cyanide.

If the impression has been gained that the operator of a modern activated sludge plant must be a master of many trades—that was the intention. However, it must be emphasized that this is made possible only by securing the cooperation of the designing engineer. This, it is believed, has been accomplished in the plant outlined in this discussion. A great deal of time and effort has been put forth in designing these facilities in such a manner as to provide the operator with a maximum of operating convenience as well as safety.

From experience with similar treatment plants of this type in the Millington Chemical Company, it is possible to say that Newton is getting one of the finest. Both the local people and the company's management can be justly proud of this installation. The combined effluent will in no way be detrimental to the fine river and the community will have gained another good neighbor.

OZONE METHOD FOR DESTRUCTION OF PHENOLS IN PETROLEUM WASTE WATERS*

By S. J. Niegowski

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The importance and desirability of maintaining a low phenols residual in surface waters is widely recognized. Fortunately waters containing phenols may be treated successfully at water works by chemical oxidation. By a similar chemical process, refinery wastes having a high phenols content may be oxidized with ozone. An ozone oxidation process is proposed as a solution to the problem of maintaining the phenols content of the plant effluent at a practical minimum.

The decomposition of ozone with time makes it necessary to generate this gas at the plant site. Commercially, ozone is generated by the passage of clean dry air or oxygen under pressure through an alternating-current, high-voltage discharge of an ozonator. Welsbach ozonators convert about 1 per cent of the through-put air to ozone. When pure oxygen alone is used, about 2 per cent is converted with the same power consumption.

For waste treatment the dilute ozone-air mixture is dispersed through the phenolic liquor. Phenolic waste liquors absorb and react with ozone very rapidly. Simple gas-liquid contacting devices such as sieve plates, or porous stainless steel or carborundum plates can be used for the dispersion of the ozonated gas through tanks or towers of waste liquor. If the waste contains tars, or substances which produce tars on ozone treatment, the dispersion device of choice is the sieve plate. For continuous waste treatment, a sieve plate tower was used in laboratory studies.

Experimental Procedure

The laboratory results were obtained according the the following experimental procedure. The source of ozone was the Welsbach T–23 ozonator operated with dry air. A 500-ml. sample of the waste liquor was placed in a gas-washing bottle equipped with a fritted glass disk for dispersion of the ozonated air. A second gas-washing bottle containing 2 per cent potassium iodide solution was used to trap any excess ozone.

The volume of the ozonized air which passed through the waste sample and the trap was measured with a wet-test meter. The concentration of the ozone in the ozonized air was determined by absorption in neutral 2 per cent potassium iodide solution and titration of the liberated iodine with standard thiosulfate solution. From the ozone concentration in milligrams per liter the volume of ozonized air required to give the waste liquor a specific dose in parts per million of ozone was calculated. When this volume had passed through the sample, the flow of ozonized air was stopped and a known portion of the sample was withdrawn for phenols analysis. Additional increments of ozone were then applied in the same manner to the remaining sample until sufficient data were obtained for plotting a complete phenols oxidation curve.

The standard 4-aminoantipyrine procedure was used for the phenols determination. Ammonium persulfate was used as the oxidant in this procedure, since lower blank color was thus obtained. The phenolic content of the sample was expressed simply as phenol.

* Presented at 38th Texas Water and Sewage Works Assn. Short School; Texas A. & M. College; College Station, Texas; Mar. 4–9, 1956.

Effect of Initial pH

Phenol can be oxidized by ozone at any pH value. Conant (1) showed, however, that the apparent oxidation potential of phenol decreases with increasing pH. It should, therefore, be more easily oxidized as the pH value increases. On the other hand, the rate of ozone decomposition increases with increasing pH. Even though less ozone is available for phenols oxidation at a high pH, an optimum pH of about 12 was observed. This high pH favors phenols oxidation, apparently at the expense of other competing oxidation reactions. The optimum pH effect was first noted in some studies of the ozone oxidation of coke oven wastes (2).

The effect of high pH value on the ozone demand of a refinery waste is illustrated in Figure 1. This sample, as received in the laboratory, had a pH of 7 and it was ozonated at this pH. For the second experiment, the pH was adjusted to 12 before ozonation. The ozone demand at pH 12 proved to be less than one-half of the ozone demand at pH 7. However, during about two-thirds of the oxidation the reaction is so rapid that the pH has practically no effect.

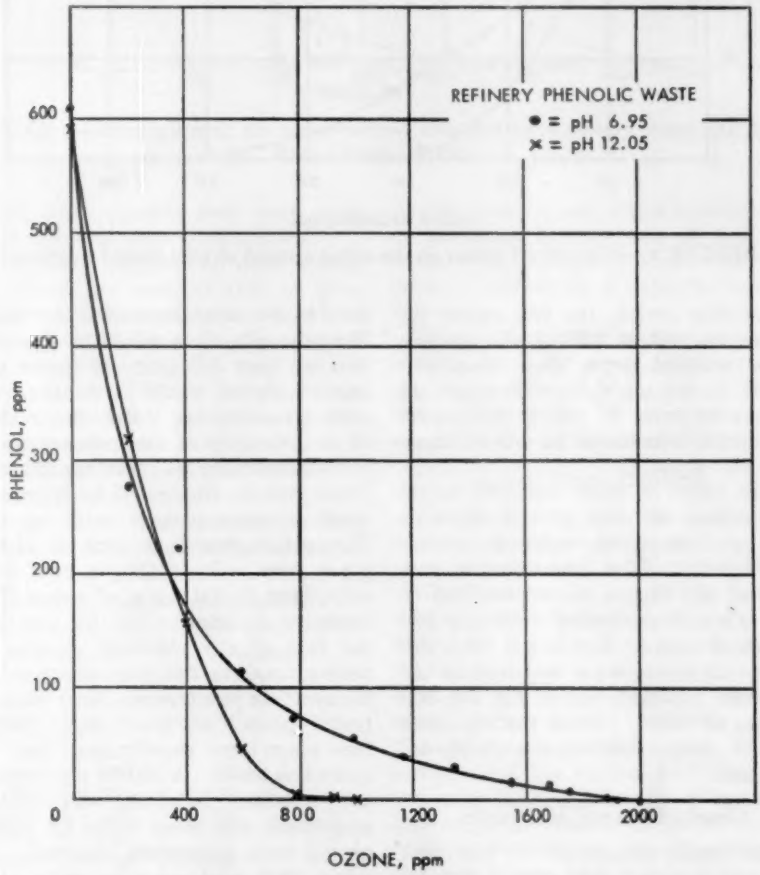

FIGURE 1.—Effect of pH values on the ozone demand of a refinery waste.

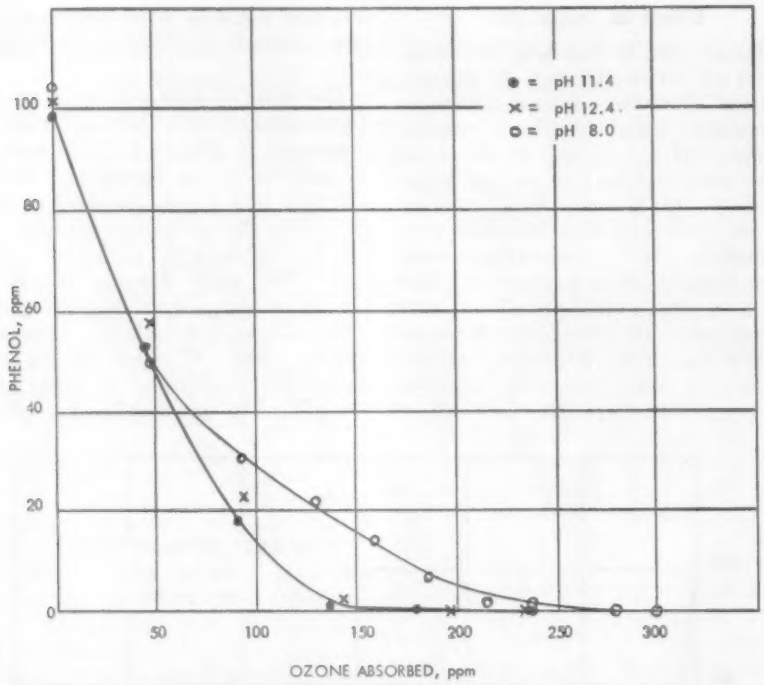

FIGURE 2.—Effect of pH values on the ozone demand of pure phenol solutions.

After this period, the two curves diverge, so that at pH 12 the phenols were reduced from more than 600 p.p.m. to 0.4 p.p.m. by 900 p.p.m. of ozone; whereas at pH 7, 0.3 p.p.m. of phenols remain at an ozone dosage of 2,000 p.p.m.

The effect of three different initial pH values on pure phenol solutions is illustrated by the oxidation curves in Figure 2. It is interesting to note that at pH 11.4, a phenol residual of 0.05 p.p.m. was reached with only 180 p.p.m. of ozone. But at pH 12.4, 220 p.p.m. of ozone were required to attain this residual, and at pH 8.0, 300 p.p.m. of ozone. Thus the optimum pH for ozone oxidation of pure phenol lies near 11.4.

Ozone Demand of Wastes

The ozone dosage at 99 per cent phenols removal was arbitrarily defined as the ozone demand of the waste. For pure phenol, it would be expected that at least 1.5 parts of ozone per part of phenol would be required for such an oxidation. But the results of an oxidation of one refinery waste proved contrary to this expectation. These results, illustrated in Figure 3, show an ozone-phenols ratio of one. The initial phenols content of 11,600 p.p.m. was reduced 99 per cent with only about 11,000 p.p.m. of ozone. The tentative explanation for this was that the rate of any chemical reaction is proportional to the concentrations of the reacting substances. More concentrated phenol solutions might therefore react more rapidly and thus require less ozone. A 10,000 p.p.m. phenol solution, however, showed no measurable difference in the 1.5 ozone-phenol ratio previously observed. It seems that perhaps this waste con-

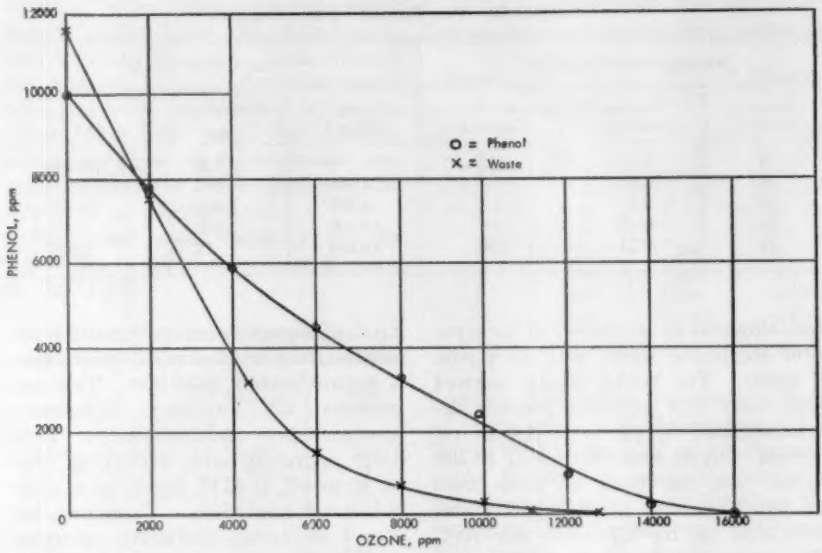

FIGURE 3.—Comparison of the ozone demand exhibited by a refinery waste and by a pure phenol solution.

tained other phenols that were more easily oxidized than phenol itself.

The ozone demand of some wastes was about the same as that of pure phenol. Others required about 10 parts of ozone for each part of phenols to achieve virtually complete removal of the phenol. For a wide range of wastes, it must be said that the average ozone requirement has been about five parts of ozone per part of phenol.

Those wastes that contained sulfides showed a very high ozone demand.

TABLE I.—Catalytic Cracking Waste

No Pretreatment		Preaeration	
Ozone (p.p.m.)	Phenols (p.p.m.)	Ozone (p.p.m.)	Phenols (p.p.m.)
0	293	0	293
1,100	175	450	63
2,000	73	780	6.5
2,920	16	970	0.24
3,390	3.0	1,140	0.18
3,800	0.6	1,260	0.16

Sulfide removal and hence a reduction of the ozone demand was effected by preaeration. Table I illustrates the effect of sulfide in a catalytic cracking waste.

The sulfide content of the untreated sample was 1,500 p.p.m.; the aerated sample contained 20 p.p.m. Thus about 2,500 p.p.m. of ozone was consumed in the oxidation of the sulfide.

Ozone Plant Capacity

The ozone treatment plant capacity required would be determined by the ozone demand and volume of the individual wastes. Two phenolic waste samples were submitted by one refinery for a study of ozone oxidation. One sample had a phenols content of only 5.4 p.p.m.; the volume of this waste, however, was 800,000 g.p.d. The other sample had 6,130 p.p.m. phenols, but the volume of this waste was only 6,300 g.p.d. The results of this study are shown in Table II.

About 96 per cent phenols destruction and 21 per cent B.O.D. reduction

TABLE II.—Two Phenolic Waste Samples

Separator Composite Sample			Waste Caustic Sample		
Ozone (p.p.m.)	Phenols (p.p.m.)	B.O.D. (p.p.m.)	Ozone (p.p.m.)	Phenols (p.p.m.)	B.O.D. (p.p.m.)
0	5.4	151	0	6,130	20,700
6	4.8	—	4,100	3,860	—
12	2.1	—	8,300	1,990	—
23	0.45	—	12,500	678	—
33	0.21	120	18,700	12	8,820

were obtained by treatment of the separator composite waste with 33 p.p.m. of ozone. The waste caustic showed more than 99.8 per cent phenols destruction and 58 per cent B.O.D. reduction with an ozone dosage of 18,700 p.p.m. On the basis of these tests the required ozone plant capacity was calculated to be 1,200 lb. per day. The separator composite would require 220 lb. for its treatment, and the waste caustic, 980 lb.

In understanding ozone economics, it must be realized that a relatively high capital investment must be made in plant equipment. Offsetting this factor, a 25-year life of the ozone equipment may be assumed as well as a low and stable operating cost. The operation of an ozone plant should require no more than a minimum of supervision, and would eliminate materials procurement, handling, and storage problems. The ozone process is simple, safe and dependable.

The cost for an ozone plant capable of producing 1,260 lb. of ozone per day, and suitable for treating 800,000 g.p.d. of separator composite and waste caustic such as described previously, is approximately $380,000. This cost includes all auxiliary equipment, treatment tank and installation. Total daily operating cost, excluding capital write-off, is $117, based on average industrial conditions. Total cost per pound of ozone, including amortization, is $0.18; per pound of phenols treated, the total cost is about $0.65.

Partial ozone treatment with proper dilution could provide a plant effluent having a phenols content of several parts per billion. Data on the treatment of four wastes from one refinery are given in Table III.

The ozone demand of the overhead receiver waste was due to sulfide. Because of its large volume, the treated wash water would determine the phenols content of the plant effluent. Its volume also provided a dilution factor of 190 to 1 for the partially treated gas receiver and reflux accumulator wastes. The phenols content of the wash water was reduced to about 40 p.p.b., with 30 p.p.m. of ozone. Its

TABLE III.—Four Phenolic Wastes from One Refinery

Overhead Receiver		Gas Receiver		Reflux Accumulator		Wash Water	
Ozone (p.p.m.)	Phenols (p.p.m.)	Ozone (p.p.m.)	Phenols (p.p.m.)	Ozone (p.p.m.)	Phenols (p.p.m.)	Ozone (p.p.m.)	Phenols (p.p.m.)
0	1.2	0	172	0	253	0	3.1
680	0.27	490	90	520	110	9	0.90
1,260	0.05	980	5.8	1,040	4.6	17	0.13
—	—	1,360	0.09	1,470	0.16	24	0.07
—	—	—	—	1,770	0.07	30	0.04

dilution with other process water would further lower the phenols content to about 20 p.p.b. Even though the phenols content of the overhead receiver could be reduced to an insignificantly low value by dilution alone, complete ozone treatment was recommended for the oxidation of the sulfide in the waste.

The ozone plant capacity for the treatment of all these wastes is given in Table IV.

TABLE IV.—Ozone Requirements

Waste	Ozone Demand (p.p.m.)	Ozone (lb./day)
Overhead receiver	1,260	23
Gas receiver	980	94
Reflux accumulator	1,040	100
Wash water	30	545
Total	—	762

Because of its small volume, the overhead receiver wastes which have a high sulfide content required only 23 lb. of ozone. The wash water, whose volume was in excess of 2 m.g.d., required 545 lb. of ozone for treatment.

The initial pH value of the first three samples was between pH 8.5 and 8.9. Sodium hydroxide was used to adjust the pH to 11.8. The wash water was ozonated at pH 8.0. Actually no pH adjustment was tried. In this case, it was believed that the additional alkali requirements might offset any saving of ozone.

Continuous Ozone Treatment

Although ozone is generated continuously, the waste treatment plant can be designed to treat the waste either in batches or by a continuous and constant flow. For continuous oxidation on a laboratory scale, a Pyrex glass pipe tower equipped with sieve plates was used. The tower was made with 9 sections of 4-in. glass pipe, each 12 in. long. The sieve plates contained about 50 holes of 1/16-in. diameter. The liquor downcomer pipes, of ½-in. stainless steel, maintained the liquid level about 6 in. above the sieve plate. Preliminary tests with pure phenol showed no significant difference between batch and continuous treatment. The results of a sample continuous treatment of phenolic wastes are presented in Table V.

TABLE V.—Continuous Ozone Treatment

Stage No.	Ozone Concentration Entering Stage (mg./cu.ft.)	Ozone Dosage (p.p.m.)	Phenols (p.p.m.)
1	0	0	115
2	0	0	105
3	0	0	115
4	0	0	113
5	0	0	105
6	139	400	19
7	308	890	2.2
8	436	1,260	0.45
9	467	1,350	0.37

The tower design proved more than adequate for the ozone treatment of this waste. Only four stages of the tower were active. Larger ozone dosages for more complete phenols removal would have spread the reaction over the other stages.

Conclusion

The ozone method for the destruction of phenols in petroleum wastes offers several advantages. Ozone treatment adds only oxygen to the wastes. This means that high ozone dosages will not change the character of the wastes by introduction of another chemical. A reduction of the B.O.D. and C.O.D. accompanies the phenols destruction. The toxicity due to phenol is reduced in the same proportion as the phenols are destroyed.

What might be called "super-ozonation" for complete phenols destruction is usually unnecessary. Even with partial ozone treatment, there will be a corresponding reduction in odor and toxicity. At those refineries

where phenol-free process or cooling water is available for dilution, only partial ozonation would be required for a practical and satisfactory treatment. A treatment plant effluent having a phenols residual of several parts per billion can be obtained by proper dilution of the partially ozonated phenolic wastes.

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2. Niegowski, S. J., "Destruction of Phenols by Oxidation with Ozone." *Ind. Eng. Chem.*, **45**, 632 (1953).

PROFESSIONAL OPPORTUNITIES

The Florida State Board of Health, Bureau of Sanitary Engineering, is accepting applications from qualified individuals for the positions of sanitary engineer, stream biologist, and sanitary chemist in its stream sanitation program. Salary is dependent on training and experience. For further information write to Paul T. Baker, Personnel Supervisor, Florida State Board of Health, P. O. Box 210, Jacksonville, Florida.

The city of Springfield, Missouri, is accepting applications for the following positions:

Sewerage System Superintendent—High school graduate, 8 to 10 years of responsible experience in construction, operation, and maintenance of sewage treatment plants, 3 to 5 years supervisory experience.

Assistant to Sanitary Engineer—High school graduate, 3 to 5 years experience in water, sewage or industrial wastes treatment.

Salaries commensurate with experience; vacation and sick leave benefits. For further information write to W. Robert Semple, Director of Personnel, Personnel Department, City Hall, Springfield, Missouri.

OPPORTUNITIES FOR GRADUATE STUDIES

Alabama Polytechnic Institute, School of Engineering, announces a program of graduate study in Sanitary Engineering, leading to the Master's degree. The total fee for graduate students is $35.00 per quarter for a full load of 15 credit hours. Graduate fellowships and research and teaching assistantships with full or partial course loads are available for those needing financial assistance. Further information may be obtained from Professor Theodore Jaffe, Civil Engineering Department, Alabama Polytechnic Institute, Auburn, Alabama.

POLLUTION REDUCTION PROGRAM FOR THE TEXTILE INDUSTRY *

By Joseph W. Masselli and Gilbert Burford

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It is axiomatic in the sanitary engineering field that textile wastes are extremely variable from mill to mill and even in the same mill, although the cause has usually been unexplained. The textile chemist could have informed the engineer that this was to be expected because he was cognizant of the many different processes and chemicals which may be used to achieve the same end result and because he also knew that such processing changes with the season, the cloth, the color desired, and the particular order involved.

Many investigations in the past have been carried out on textile wastes and their treatments, but unfortunately little information was included on the type and weight of cloth involved, on the processes and chemicals used, and on the volume of waste discharged. Because of this, no general conclusions other than the variability axiom previously mentioned could be drawn on textile wastes. From the data included it could not be ascertained whether the bulk of the pollution came from natural impurities in the fiber or from the chemicals used to process it. No accurate estimate on the pollution load to be expected from a given process or mill could be made and no detailed information on the chemical compounds actually discharged in the waste was obtainable.

In 1949 the New England Interstate Water Pollution Control Commission, which is dedicated to abatement of pollution and assisting industries faced with pollution problems, with the aid of federal funds initiated an investigative program on textile wastes. The main objectives were to determine the sources of pollution in these wastes and the possibility of using a package treatment unit for them.

Two of the most important conclusions from the studies were that (a) considerable reduction in pollution may be obtained by substitution of low-B.O.D. process chemicals for high-B.O.D. chemicals normally used and (b) a process chemical inventory and B.O.D. survey is of considerable aid in pin-pointing the sources of pollution and determining which chemicals to replace in order to obtain pollution reduction (1). Another interesting revelation was that the textile industry has in its files much detailed information which is useful to the sanitary engineer in this type of survey. In many instances, a pollution survey has also indicated methods whereby economies in processing may be effected.

In the investigations on textile mills, the usual analytical survey was made of the running rinses and dump discharges from the various machines and baths in the mill. The volume of discharge, the pH, alkalinity, B.O.D., solids, etc., content of each waste was determined. From these data, the pollution potential of each process expressed in pounds of B.O.D. per 1,000

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† Maintained for the Connecticut State Water Commission.

TABLE I.—Major B.O.D. Wastes in a Cotton Finishing Mill

Department	Process	B.O.D.	
		(lb.)[1]	(%)[2]
Desizing		53	35
Scouring	Pressure kier, first scour	53	16
	Pressure kier, second scour	8	1
	Continuous scour	42	15
	Sub-total	—	32
Dyeing		0.5–32	15–30
Printing	Color shop wastes	12	7
	Wash after printing, with soap	17–30	17–30
	Wash after printing, with detergent	7	7
	Sub-total	—	15–35
Bleaching	Hypochlorite bleach	8	3
	Peroxide bleach	3	1
Mercerizing		6	1
Total		125–250	

[1] Per 1,000 lb. of cloth.
[2] Per cent of total.

lb. of cloth was determined. It is desirable to point out that these are important values which may be useful to plants and regulatory agencies who are desirous of determining the pollution load of a mill. From calculations using these values, the amount of cloth to be processed and the amount of water available for dilution in the receiving stream, determination as to whether or not treatment will be necessary may be made. In this way mills that may wish to locate on a given stream can be told ahead of time whether or not they must consider treatment of wastes in their plans.

From the analytical survey of the individual wastes, no knowledge concerning the causes or reasons for the B.O.D. in the wastes is obtained. To get this information, detailed data on the chemicals used in the process are necessary. These are usually readily available at most plants in their process flow sheets and in their chemical inventory. The information is carefully inspected to determine the process chemicals used in greatest amounts. Samples of these chemicals are analyzed for B.O.D. to determine their polluting strength. From such a survey the pollution potential produced in the waste by these chemicals may be determined and cross-checks on the analytical survey of the wastes may be obtained.

Cotton Mill Pollution Sources

The pollution potential of cotton processes and chemicals are recorded in Tables I and II, respectively. These results indicate that the major wastes are the desize wastes (35 per cent of the total mill B.O.D.), kiering or scouring wastes (33 per cent), and dye or printing wastes (20 to 35 per cent).

The desizing process removes most of the slashing starch which was put on the fibers to aid in weaving. This starch is converted by enzymic or acid hydrolysis to glucose. Practically all of the B.O.D. is produced by the glucose hydrolyzed from the starch, since the enzymes and acids used produce little or no B.O.D. Glucose is, consequently, one of the major constituents and B.O.D. sources in practically all cotton mill wastes.

It has been reported (2) that considerable reduction in size add-on may be obtained if the small amount of

fat used as a plasticizer in the sizing make-up is reduced or omitted. Since size add-ons average 5 to 15 per cent, appreciable reductions may be obtained, with consequent reduction in pollution.

Further reductions are obtainable through substitution of low-B.O.D. substitutes for starch (50 to 60 per cent B.O.D.). Hydroxyethylcellulose and carboxymethylcellulose (3 per cent B.O.D.) have been used but not widely because of the price differential.

TABLE II.—Consumption and B.O.D. of Cotton Process Chemicals

Chemical	Use (lb.)[1]	B.O.D.	
		(%)[2]	(lb.)[1]
(a) Sizing and Thickening Agents			
B-2 gum	22	61	13.4
Wheat starch	16	55	8.8
Pearl cornstarch	14	50	7.0
Bryte gum No. 745	4	61	2.4
KD gum	4	57	2.3
Slashing starch[3]	96	—	53.0
Carboxymethylcellulose	—	3	—
Total	150	—	82.9
(b) Others			
Tallow soap	20–100	150	30–150
Nacconal NR	1	4	0.04
Ultrawet 35 KX	—	0	0
Acetic acid, 80%	27	52	14.0
Mixture of 18 dyes	37	7	2.6
Cream softener, 25%	20	39	7.8
Formaldehyde-bisulfite condensate	14	27	3.8
Glycerine	3	64	1.9
Sodium hydrosulfite	11	22	2.4
Urea	13	9	1.2
Finish T.S.	8	39	3.1
Kierpine extra	5	61	3.1
Merpol B	4	44	1.8
Glucose	—	71	—
Gelatin	—	91	—

[1] Per 1,000 lb. of cloth.

[2] Per cent B.O.D. based on weight of chemical; for example, 1 lb. of B-2 gum (61 per cent B.O.D.) would require 0.61 lb. of oxygen for stabilization.

[3] Calculated from desize waste B.O.D.

Snyder (3) reported that use of a 65 per cent starch-35 per cent carboxymethylcellulose size at a lower add-on caused appreciable reductions in the desize waste B.O.D. He also reported that polyvinyl alcohol (1 per cent B.O.D.) and polystyrene derivatives (1 per cent B.O.D.) may prove suitable for cotton sizing. By reason of B.O.D. reductions obtainable through in-plant processing changes in desizing and dyeing, he feels that a 70 per cent B.O.D. reduction is readily obtainable, consequently eliminating the cost of constructing and operating a treatment plant to treat the wastes.

Kiering or continuous scouring is done on cotton to make the fiber more amenable to dyeing and processing. These wastes contain the natural impurities dissolved from the cotton fiber (waxes, pectins, alcohols, etc.), in addition to organic scouring assistants usually used in the highly caustic kiering solution (1 to 3 per cent caustic soda). Calculations indicated that 80 per cent of the B.O.D. in the kier and scour waste comes from the natural impurities and 20 per cent comes from the organic assistants.

The washed kiered cloth on subsequent rinsing contributes no further B.O.D. to the water, indicating that any subsequent pollution must come from the process chemicals. The results therefore indicate that 30 to 40 lb. of B.O.D. is extracted as natural impurities from each 1,000 lb. of cotton kiered or scoured. This usually amounts to 20 per cent of the total plant B.O.D., the remaining 80 per cent being contributed by the process chemicals.

Inasmuch as most plants wish to remove most of the natural impurities from the cloth, the maximum reduction apparently obtainable in this waste is 20 per cent by substitution of the organic scouring assistants. However, quite often only a light scour is sufficient for certain dyeing or processing and pollution reduction may be ob-

tained in this manner. In addition, some mills use peroxide, perborate, peracetic acid and chlorine dioxide in conjunction with the usual kiering and scouring methods. No adequate study has been made of the resultant B.O.D. reductions so obtained, but it is expected to be appreciable since Nemerow (4) showed that simple aeration and neutralization without seeding reduced the B.O.D. of kier wastes by 68 per cent. With the powerful oxidizing agents mentioned and the high-temperature, highly-caustic kier solution normally used, high reduction in B.O.D. may be obtained. Research work should be done on catalyzing the rate of reaction in such a medium, either while the kiering is being done or separately in a special tank if necessary. In this manner, the organic matter will be oxidized by the oxidizing agents rather than by the dissolved oxygen in the stream.

The pollution potentials of the dyeing wastes are extremely variable because of the different dyes and processes, and also because of the extremely wide choice of dispersing, emulsifying, leveling, softening, reducing, oxidizing, acidifying and washing agents used. Dyeing assistants used to emulsify, disperse, or "carry" the dye may include acid amides, amine condensates, long-chain alcohol sulfates, sulfonated castor oils, vegetable oils, methyl oleyl tauride, sulfonated or emulsified pine oil, coconut oil, alkylarylsulfonates, ethylene oxide condensation products, organic solvents, etc. Some of these have little or no B.O.D., whereas others have 60 to 150 per cent B.O.D.

Some plants use soap (150 per cent B.O.D.) extensively in dyeing to pre-wash, level, soften, and final-wash the cloth. If used in these four steps separately, as much as 60 lb. of B.O.D. per 1,000 lb. of cloth will be contributed by the soap alone. Many plants use low-B.O.D. detergents in place of soap, with considerable reduction in B.O.D., as indicated later herein.

Reducing agents for vat and sulfur dyes may be sulfide, hydrosulfite, glucose, xylose, etc. Chromate and perborate are widely used oxidizing agents, usually used with acetic acid as the acidifying agent. The acetic acid so used may comprise 50 to 90 per cent of the dye waste B.O.D. and 15 to 30 per cent of the total mill B.O.D. It may be readily replaced in most instances, by sulfuric acid or ammonium sulfate (0 per cent B.O.D.). The entire oxidizing step may be replaced completely by use of a steam chamber, thus eliminating not only the acetic acid, but the oxidizing agent as well.

In addition to the wide choice of chemicals available, dyeing may be done on jigs or on the more economical continuous basis, using padding methods for add-on of the dye. The continuous basis is reported to consume less chemicals, with consequent reductions in pollution.

Data in Table III indicate that sulfur and vat dyeing produce the greatest B.O.D. loads (30 to 32 lb.), whereas direct dyeing produces extremely low loads (0.5 lb.). Continuous vat dyeing reduces the B.O.D. load by 40 per cent, when it replaces vat dyeing on jigs.

From the discussion it can be readily seen that dye wastes are probably the main cause of the extreme variability of textile wastes because of the different dye types, processes, chemicals, and methods available. In plants

TABLE III.—B.O.D. Contribution of Cotton Dye Processes

Process	B.O.D. (lb.)[1]
Vat dye, continuous	18
Vat dye, jig	32
Naphthol, jig	14
Direct, jig	0.5
Sulfur, jig	31

[1] Per 1,000 lb. of cloth.

which dye most of their cloth, the dye wastes are expected to contribute 20 to 35 per cent of the total plant B.O.D. Most of this B.O.D. is comprised in the soap and acetic acid used, and substitution of these two chemicals in these processes is expected to reduce the plant B.O.D. considerably.

Wastes from printing include the waste from the color shop, where printing pastes are made, and wastes from the wash after printing. Color shop wastes are produced mainly from the cleaning of tubs, filter cloths, dippers, etc., used in preparing, measuring and filtering the pastes, and also from dumping of unused printing pastes. All of the solutions in the color shop are extremely concentrated starch pastes containing reducing agents, glycerine, and gum. These pastes average 60,000 to 120,000 p.p.m. B.O.D. and only small amounts are needed to produce appreciable B.O.D.'s in the rinse water. If a little care is taken to provide wiping cloths, standing rinses before running rinses, extra drain time for tubs, etc., most of the paste may be segregated in concentrated form and burned or carted to a dump instead of being discharged to the receiving stream. B.O.D. reductions of 40 to 80 per cent should be obtained in color shops through this procedure.

Wash after printing may be done with soaps or synthetic detergents. It must be remembered that the back-grey cloth must be washed when it becomes soiled. In printing of light cloth, considerable seepage of printing paste onto the back-grey cloth occurs. Consequently, one yard of back-grey cloth will have to be washed for each yard of cloth printed. In printing thick drapery cloth, the back-grey cloth may be used several times before becoming soiled and one yard will have to be washed for every three to six yards of cloth printed. If soap is used, the pollution load may be increased 15 to 50 lb. for each 1,000 lb. of cloth printed. In one mill reductions of 90 per cent in the B.O.D. of wash waters were obtained by substituting an alkylarylsulfonate detergent for soap.

Soap usage varies considerably from mill to mill, but it is expected that its substitution by low-B.O.D. detergents will cause reductions of at least 15 per cent in any mill and probably as high as 50 per cent in some mills.

Bleaching and mercerizing wastes contribute only 5 per cent of the total plant B.O.D. because of their low pollution potential. It may be noted that peroxide bleaching produces only 3 lb. of B.O.D. per 1,000 lb. of cloth, whereas hypochlorite produces 8 lb. Mercerizing wastes produce 6 lb. of B.O.D., usually associated with considerable alkalinity.

The results indicate, therefore, that cotton mills discharge approximately 125 to 250 lb. of B.O.D. for every 1,000 lb. of cloth processed. In other words, the B.O.D. load is 12.5 to 25 per cent of the weight of the cloth processed. Major reductions in B.O.D. may be produced in desizing, printing, dyeing, and washing, through substitution of low-B.O.D. chemicals for high-B.O.D. chemicals. Specifically, hydroxyethylcellulose or carboxymethylcellulose may replace starch; synthetic detergents may replace soap; and ammonium sulfate, diammonium phosphate, or sulfuric acid may replace acetic acid. Peroxide bleaching should be used in place of hypochlorite bleaching, and continuous dyeing methods should be used whenever possible. Low-B.O.D. kiering assistants and dispersing, reducing, and leveling aids for dyeing should be sought. By means of these changes it is expected that reductions of 50 to 80 per cent in B.O.D. may be readily obtained. In many instances such a reduction may obviate the need for building and maintaining a waste treatment plant or will allow location of a plant on a receiving stream which previously

could not handle the mill's waste without causing a nuisance.

Research investigations should be started on catalytic oxidation of kier and scour liquors, because this waste will be the major waste after a substitution program as previously outlined is carried out.

Woolen Mill Pollution Sources

In the United States the actual wool fiber content in grease wool taken from the sheep's back averages only 40 per cent, the remaining 60 per cent being natural impurities such as sand, grease, suint, and burrs. Consequently, when 2½ lb. of grease wool is scoured, only 1 lb. of scoured wool is produced. In other words, for every 1,000 lb. of scoured wool produced, 1,500 lb. of impurities are discharged to waste. In addition to these natural impurities, 300 to 600 lb. of process chemicals are discharged to waste. This total of 2,000 lb. compares with approximately 800 to 1,000 lb. of impurities and chemicals discharged to waste for each 1,000 lb. of cotton processed.

TABLE IV.—B.O.D. Extracted in Laboratory Scouring Experiments

Code	Description	Grease (%)	B.O.D. (%)
	(*a*) Raw Greasy Wools, Unopened		
A	——	17.6	23.6
B	12-month Texas	15.2	20.9
D	4-month Texas	13.8	37.8
E	Cape	9.7	14.0
F	12-month Texas	10.5	15.7
	(*b*) Raw Greasy Wools, Opened		
I	Texas, fall	11.2	20.8
J	12-month Texas	13.5	26.9
	(*c*) Grease Extracted		
I	Texas, fall	0	10.7
J	12-month Texas	0	12.5
	(*d*) Scoured Wools		
G	Texas, fall	2.4	2.5
H	12-month Texas	1.2	0.9
C	——	—	1.7
K	12-month Texas	—	1.4

Laboratory scouring experiments reported in Table IV reveal that 200 to 250 lb. of B.O.D. from natural impurities alone are discharged for each 1,000 lb. of scoured wool produced. Experiments with wools from which the grease was extracted with ether indicated that approximately 50 per cent of this load was due to grease and 50 per cent due to suint salts and other impurities. This indicates that even if solvent scouring is used for grease recovery, the suint salts and other impurities left in the wool will still produce 100 to 125 lb. of B.O.D. for each 1,000 lb. of scoured wool. Consequently, grease recovery in itself will not necessarily eliminate a pollution problem in a scouring mill.

It is interesting to note also that wools scoured in a commercial scouring train produced 10 to 20 lb. of B.O.D. per 1,000 lb. of wool when re-scoured in the laboratory.

Results from an analytical survey of a wool scouring and finishing mill are recorded in Method I of Table V. These show that scouring for grease and suint removal produced 55 per cent of the total plant B.O.D., stock dyeing with acetic acid produced 11 per cent, and wash after carding and fulling produced 33 per cent. Neutralizing after carbonizing produced only 0.5 per cent of the total B.O.D. An extremely high pollution load of 451 lb. of B.O.D. for each 1,000 lb. of cloth was discharged to the stream. In other words, a B.O.D. load of 45 to 50 per cent of the weight of the cloth is discharged to the stream while scouring and processing. This may be compared to 12.5 to 25 per cent for cotton processing.

Calculations indicate that the major producers of B.O.D. in scouring and finishing mills are grease and suint

TABLE V.—Pollution Potential of Woolen Processes

Method	Process	B.O.D. (lb.)[1]	Reduction (%)
I	Scour with soap	250	
	Stock dye with acetic acid	49	
	Card Full with soap Wash with soap	150	
	Neutralize after carbonizing	2	
	Total	451	—
II	Scour with syndet	221	
	Stock dye with amm. sulfate	9	
	Full with syndet Card with 20 per cent B.O.D. oil Wash with syndet	64	
	Neutralize after carbonizing	2	
	Total	296	34
III	Solvent scour, recover grease	0	
	Wash out suint with syndet	100	
	Stock dye with amm. sulfate	9	
	Card with 3 per cent B.O.D. oil Full with syndet Wash with syndet	50	
	Neutralize after carbonizing	2	
	Total	170	62
IV	Solvent scour, recover grease and suint	0	
	Wash with syndet	10	
	Stock dye with amm. sulfate	9	
	Card with 3 per cent B.O.D. oil Full with syndet or acid Wash with syndet	30	
	Neutralize after carbonizing	2	
	Total	51	89

[1] Per 1,000 lb. of cloth.

(50 to 60 per cent), soap (25 to 35 per cent), and acetic acid (5 to 20 per cent).

Grease and suint cannot be substituted for, but they may be recovered and burned or sold. A new solvent scouring process using methyl and isopropyl alcohols is reported to recover grease and suint salts effectively (5). The main objection to the method is the cost and the poor market value of the recovered grease and suint. Research investigations should be made not only to perfect the process, but also to find markets for the lanolin, cholesterol, triterpene, and long-chain alcohols present in the recovered products (6). A re-investigation by qualified organic chemists on the basis of the newer technological needs may provide an answer to this pressing problem.

Synthetic detergents are being used in place of soap for scouring and washing in many mills, but have not yet won a definite place in fulling, although many mills have experimented with them. The main objection to their use has been cost and "hand" of the cloth. These may be eliminated in the future and considerable reduction in B.O.D. would result.

Acid fulling has been suggested for cloth fulling (7)(8), but is not used extensively. This would completely eliminate soap and in combination with

synthetic detergents would greatly reduce B.O.D. loads. Because of its great value in reducing pollution, this method should be re-evaluated by the textile industry and used whenever possible. Two plants have reported that acid fulling is satisfactory for cloth used for wearing apparel.

Acetic acid is widely used in dyeing wool and often in large amounts for deep shades. It is readily replaceable by ammonium sulfate, diammonium phosphate, and sulfuric acid. One mill which used ammonium sulfate reduced the B.O.D. of the dye wastes by 83 per cent (9).

Methods II, III, and IV of Table V indicate the reductions possible by using these substitute chemicals or processes as previously listed. It should be noted that Method IV, which should be strived for by the industry, produces reductions of 89 per cent in a scouring and dyeing mill.

Most of the woolen mills in the United States are dyeing and finishing mills which purchase scoured wool from commercial scourers. In such mills the contribution of the wool to the plant B.O.D. is negligible, as the grease and suint are already removed. The B.O.D. load in such mills will be approximately 200 lb. per 1,000 lb. of wool processed, 24 per cent being contributed by dye wastes, 75 per cent by wash after fulling wastes, and 1 per cent by neutralizing after carbonizing wastes. The soap, acetic acid, and carding oil used will contribute 80 to 95 per cent of the plant B.O.D. Substitution of synthetic detergents and ammonium sulfate for soap and acetic acid should produce reductions of 60 to 90 per cent in the plant B.O.D. Even if no satisfactory substitute for soap in fulling is found, alum treatments of only the fulling wastes will be necessary to obtain reductions of 70 to 90 per cent in such mills.

Proper process chemical substitution, therefore, will produce considerable B.O.D. reduction in woolen mill wastes. Research investigation on solvent scouring for grease and suint recovery should be carried out, along with a basic study on the recovered constituents and possibility of their use. Acid fulling should be re-evaluated and used wherever possible.

Pollution Sources from Finishing of Synthetic Fibers *

All of the synthetic fibers are essentially pure chemical compounds and have no natural impurities. Because of this and the less severe scouring necessary, pollution loads would be expected to be lower with synthetics. However, some of the synthetics, particularly Orlon and Dacron, are difficult to dye and require large amounts of carriers and swelling agents, many with very high B.O.D.'s, to produce the desired shades of color. Double dyeing and double scouring quite often are necessary, particularly with blends.

Much research on the chemical make-up, degree of polymerization, new methods, etc., is being carried on to reduce the dyeing problems; consequently, this phase of textile manufacturing is in a considerable state of flux. The variability of textile wastes will be greatly increased with increasing usage of the new fibers.

Many of the new synthetics are susceptible to the pick-up of static electricity and chemical manufacturers have prepared antistatic compounds which not only reduce this problem but also act as size and lubricating agents. Most of these compounds are used at low add-ons, (0.5 to 3 per cent) and in addition have low B.O.D.'s. Some of the more common sizes used (10) are polyvinyl alcohol (1 per cent B.O.D.), styrene-base resins (1 per cent) and polyacrylic acid (1 per cent). These compare with the fairly high B.O.D. of starch

* Most of the data for this section have been taken from a report to be published by the New England Interstate Water Pollution Control Commission.

(50 to 60 per cent) and its very high add-on of 5 to 15 per cent. Gelatin (91 per cent B.O.D.) is often used for rayon sizing and is expected to increase the total B.O.D. load considerably when so used.

TABLE VI.—Pollution Potential of Synthetic Fiber Processes

Procedure	Chemical	B.O.D.		
		Chemical (%)[1]	(lb.)[2]	Of Total (%)[3]
Acetate scour and dye	Antistat, lub. oil	—	15.0	44
	2% sulfonated oil	52	10.4	31
	1% syndet	5	0.5	2
	2% aliphatic ester	41	8.2	24
	2% softener	0	0	0
	Total	—	34.1	—
Rayon scour and dye	Antistat, lub. oil	—	15.0	50
	3% syndet	14	4.2	14
	2% soluble oil	53	10.6	36
	10–30% common salt	0	0	0
	Total	—	29.8	—
Orlon scour and dye:				
Scour	Antistat, lub. oil	—	15.0	12
	2% soaps	150	30.0	24
First dye	0.5% syndet	0	0	0
	3% formic acid	20	6.0	5
Second dye	1% wetting agent	14	1.4	1
	3% phenolic compounds	200	60.0	48
	3% copper sulfate	—	—	—
	2% hydroxy amm. sulfate	4	0.8	1
Scour	2% syndet	0	0	0
	1% pine oil	108	10.8	8
	Total	—	124.0	—
Nylon scour and dye:				
Scour	Antistat, lub. oil	—	15.0	29
	1% soaps	150	15.0	29
	1% fatty esters	55	5.5	11
Dye	2–4% sulfonated oils	56	16.8	32
	Total	—	52.3	—
Dacron scour and dye:				
Scour	Antistat. lub. oil	—	15.0	9
	1% nonionic syndet	5	0.5	0
Dye	4% acetic acid (84%)	58	23.0	13
	10% *o*-phenyl phenol	138	138.0	78
Other possible carriers	6% p-phenyl phenol	—	—	—
	40% benzoic acid	165	(660.0)[4]	(94)[4]
	40% salicylic acid	141	(564.0)[4]	(94)[4]
	30% phenylmethylcarbinol	150	(450.0)[4]	(92)[4]
	Total	—	176.5	—

[1] Per cent B.O.D. of chemical.
[2] Per 1,000 lb. of cloth.
[3] Per cent of total process B.O.D. contributed by the chemical.
[4] Estimated.

Since the B.O.D. contribution from the natural impurities and the sizes used for synthetics is low, the pollution load will depend mainly on the chemicals used in dyeing the fiber. As in cotton dyeing, therefore, the amount of soap and the type and concentration of the leveling, softening, dispersing, and emulsifying agents used will greatly affect the pollution load.

The pollution potential sources from the scouring and dyeing of rayon, acetate, nylon, Orlon, and Dacron are recorded in Table VI.

It will be noted that the antistatic-lubricating oil contribution in all is recorded at 15 lb. per 1,000 lb. of cloth. This value was the average value found in laboratory scouring experiments with the different cloths. These experiments verified the observation previously noted that size contributions from the new fibers were expected to be low, excepting when gelatin was used.

It must be pointed out, also that no contribution for waterproofing is recorded, although it is known that considerable amounts of cloth are so treated. Usually the waterproofing mixture is aluminum acetate or formate mixed with gelatin and a dispersed wax (11). The aluminum salts hydrolyze, releasing acetic and formic acids, which probably account for a considerable part of the B.O.D. from the process. The gelatin, wax solvent, and wax itself account for the remainder of the B.O.D. The waterproofing process has been found to contribute 10 to 30 lb. of B.O.D. per 1,000 lb. of cloth.

Data recorded in Table VI indicate that acetate and rayon processing produce fairly low B.O.D. loads of approximately 30 lb. The antistat, sulfonated, and soluble oils produce the bulk of this pollution. If gelatin were used for sizing and waterproofing done, the load would be more than doubled.

In nylon scouring and dyeing, loads of 50 to 60 lb. are produced. The antistat, soap, and sulfonated oils contribute 90 per cent of this B.O.D. Soap substitution may reduce the B.O.D. load by 30 per cent.

Orlon scouring and dyeing usually involves double-scouring and double-dyeing. Soap or syndets may be used for scouring, whereas formic acid, phenol, or phenolic compounds may be used for dyeing. In the cuprous ion method 2 to 10 per cent copper sulfate (OWF) * reduced by hydroxy-ammonium sulfate, sodium bisulfite, or glyoxal may be used with as much as 10 per cent phenol (12). Since phenol has a very high B.O.D. (200 per cent), its use will produce fairly high B.O.D. loads. In addition to its high B.O.D., however, phenol causes tastes and odors in drinking waters and cooked fish when present in the water in concentrations as low as 0.005 p.p.m. In other words, 1 lb. of phenol in 24,000,000 gal. of water will cause taste and odor trouble. Because of this, phenol usage is expected to cause considerable trouble if appreciable Orlon dyeing is done.

The results show that Orlon scouring and dyeing will produce approximately 120 to 130 lb. of B.O.D. per 1,000 lb. of cloth when phenol is used at 3 per cent OWF. Phenol contributes approximately 50 per cent of this load; soap, antistat, and pine oil contribute most of the remainder. Soap substitution may reduce the B.O.D. by 24 per cent. Phenol may be removed by solvent recovery (13) or may be biologically oxidized. If oxidized, the toxic copper ion, which is usually present in concentrations of 100 to 500 p.p.m. in the dye bath discharge, must be removed first by precipitation with lime.

The recorded data indicate also that Dacron scouring and dyeing represents a severe pollution problem because of the large amounts of high-

* On weight of the fiber.

TABLE VII.—Process Chemical B.O.D.

Chemical		B.O.D. (%)[1]
Name	Composition	
(a) Soaps		
Non-pareil (92%)	Sodium salt of fatty acid	140
Rome soap flakes	Sodium salt of fatty acid	122
Special textile flakes	Sodium salt of fatty acid	112
Soap	Sodium salt of fatty acid	150
Ivory Snow	Sodium salt of fatty acid	141
Lux	Sodium salt of fatty acid	147
Super Suds	Sodium salt of fatty acid	97
(b) Synthetic Detergents		
Ethofat C/15	Polyethoxyethanol fatty acid ester	100
Ethofat C/60	Polyethoxyethanol fatty acid ester	22
Ethomid HT/15	Polyethoxyethanol fatty acid amide	100
Ethomid HT/60	Polyethoxyethanol fatty acid amide	9
Exol XP Special	—	70
Iberscour	—	53
Igepal	Ethylene oxide alkyl phenol condensate	4
Igepal CA-630	Ethylene oxide alkyl phenol condensate	13
Igepal CA-conc.	Ethylene oxide alkyl phenol condensate	7
Igepon T-77	Sulfonated amide	166
Igepon AP-78	Oleic ester of sodium isothionate	121
Kreelon 8D	Sodium alkylarylsulfonate	15
Kreelon 8G	Sodium alkylarylsulfonate	23
Rinsol	—	72
Sandopan TLF	Sulfonated fatty amide	5
Santomerse 3	Sodium alkylarylsulfonate	9
Solpinol Special	Pine oil compound	70
Solvent A	—	25
Solvent GTS	Pine oil preparation	41
Solvent T	—	25
Solvex	—	1
Strodex	Sulfated amide condensation	12
Supertex E	Fatty acid soaps, solvent, and cresylic acid	25
Kyro AC	Amine condensate	12
Kyro EO	Polyethylene oxide condensate	0
Syntholite 100	Sulfated secondary alcohol	10
Triton 770	Alkylaryl polyether sulfate	9
Triton 771 conc.	Polyether sulfate	1
Ultrawet DS	Arylalkyl ether sulfate	50
Ultrawet 35K	Sodium alkylarylsulfonate	0
Duponol C	Lauryl sulfate	125
Duponol D paste	Long-chain alcohol sulfate	45
Duponol RA	Long-chain alcohol sulfate	33
Duraline	Solvent-type detergent	16
Monatone A	Built soap gel	20
Naccosol A	Sodium alkylnaphthalene sulfonate	0
Nacconol NR	Sodium alkylarylsulfonate	2
Nacconol NR8E	Sodium alkylarylsulfonate	0
Nekal NF	Alkylarylsulfonate with organic solvent	12
600 Neutronyx	Aromatic polyglycol ether	0
Orvus AB	Alkylarylsulfonate	8
Orvus Neutral granules	Alkylarylsulfonate	3
Orvus Extra granules	—	9
Parval	Fatty amine condensate plus amine soap	5
Peregal O.K.	Cationic ethylene oxide condensation	2
Pluronic F68	Polyglycol ethers	12
All	—	4
Dreft	—	49
Unico Scour M	Alkylnaphthalene sulfonate	10
Saponite	—	83
Zipsuds	Soap "break"	56
Dri-suds	—	43
Tergitol NPX	—	2
Tween 80	Sorbitan monooleate polyoxyalkylene	35
Sodium alginate	—	36
(c) Sizes, Spinning, and Carding Oils		
KD gum	Starch	57
RTC gum	Starch-Urea	12
Starch No. 450	Starch	46
Tragtex R	Gum tragacanth	2
Wheat starch	Starch	55
Ambertex M	Starch paste	2
Amioca	Waxy-maize starch	7
B-2 gum	Starch dextrins	61
Brytex gum 745	Starch	61
Crystal gum	Converted starch	9
Dextrin	Converted starch	50
Pearl cornstarch	Starch	50
Nicol starch	Starch	57
Morningstar starch	Starch	47
Carboxymethylcellulose	Carboxymethylcellulose	3
Hydroxyethylcellulose	Hydroxyethylcellulose	3
Nopco 1656	Soluble fatty ester	12
Proxol T	Mineral oil plus nonionic emulsifier	20
Ahco Nylon warp size	—	34
Peter Cooper size	Glue	118
Gelatin	Gelatin	100
Ucon H-6	Polyalkalene glycols	4
Ucon H-15	Polyalkalene glycols	4
Picking oil	—	13
Glue	Glue	66
Elvacet	—	1
Avcosol 20	Waxy sorbitol ester	42

[1] Per cent B.O.D. is based on weight of chemical; for example, 140 per cent B.O.D. indicates that each pound of chemical will exert 1.4 lb. of B.O.D.

TABLE VII.—Process Chemical B.O.D.—(Continued)

Chemical		B.O.D. (%)[1]
Name	Composition	
Orthocryl 25	Polyacrylic acid	1
Stymer R	Styrene maleic anhydride salt	1
Stymer S	Styrene maleic anhydride salt	1
Elvanol	Polyvinyl alcohol	1
(d) Special Finishing Agents		
Finish T.S.	Soya bean oil	39
Urea	NH_2CONH_2	9
Wool finish B	High carbohydrates and enzymes	57
Zelan AP paste	High molecular nitrogen compounds	15
Zeset S	Resin solution	7
Aerotex M-3 resin	Melamine-formaldehyde	23
Aerotex softener H	Mixed cationic-anionic long-chain derivatives	3
Aerotex syrup 250 conc.	Urea-formaldehyde condensate	5
Abcovel G	Fatty carbamide	2
Avitex SF	Long-chain alcohol sulfate	35
Avitex R	High alkylamine	5
Avitone A	Sodium hydrocarbon sulfate	2
Casein	Casein	25
Catalyst AC	Nonammonium stable organic salt	2
Cetosol SF	Resin	24
Concental H60	Highly sulfonated organic material	100
Dimethylolurea	Dimethylolurea	10
Lustramine	—	33
Lustrasol	—	20
Meleine RS	Aliphatic amino compound	30
Methacrol FNH	Resin emulsion	4
Resloom HP Special	Melamine-formaldehyde condensate	13
Resloom M 75 G	Melamine-formaldehyde condensate	14
Rhonite 313	Urea-formaldehyde resin	11
Rhonite 610	Urea-formaldehyde resin	5
Rhonite R-1	Urea-formaldehyde resin, modified	7
Norane W-1	Wax emulsion	70
Norane W-2	Metal-organic dispersion	1
Alum-wax	Alum-wax dispersion	30
Softener cream	Sulfonated tallow oil	39
(e) Emulsifying Agents		
Kierpine Extra	Sulfonated tall and pine oils	61
Sandozol KB	Sulfonated vegetable oil	15
Triethanolamine	$(HOCH_2CH_2)_3N$	1
B.P. solvent	Pine oil mixture	94
Merpol B	Alcohol sulfate	44
Sulfonated castor oil	Castor oil, sulfonated	52
Sulfonated vegetable oil	Vegetable oil, sulfonated	59
Nopco 1111	Sulfonated coconut oil	96
Rexan O	Ethylene ether condensation	2
Pentex 46	—	35
Capracyl	—	5
(f) Dyeing		
Formaldehyde 37%	HCHO	37
Formic acid 85%	HCOOH	20
Glucose corn syrup	Glucose $C_6H_{12}O_6$	53
Glycerine	$CH_2CH\ CHOH\ CH_2OH$	64
Sodium acetate	$CH_3\ COONa$	32
Sodium hydrosulfite	$Na_2S_2O_4$	22
Sodium sulfide	Na_2S	22
Sulfoxite	$NaHSO_2 \cdot HCHO \cdot 2H_2O$	27
Acetic acid, 56%	CH_3COOH	35
Acetic acid, 80%	CH_3COOH	52
Acetic acid, 84%	CH_3COOH	62
Ammonium sulfate	$(NH_4)_2\ SO_4$	0
Sulfuric acid	H_2SO_4	0
Aniline oil	$C_6H_5NH_2$	150
Anthomine	High molecular weight fatty esters and nitrogen compounds	9
Carbogen	—	2
Lanamine tip	Albumen derivative	9
Metachloron	—	0
Monochlorobenzene	C_6H_5Cl	3
Dowicide A	*o*-phenyl phenol	138
Salicylic acid	$C_6H_4(OH)COOH$	141
Benzoic acid	C_6H_5COOH	165
Phenylmethyl-carbinol	—	150
Phenol	C_6H_5OH	200
(g) Miscellaneous		
Ethanol	C_2H_5OH	125
Ethylacetate	$C_2H_5COOCH_3$	85
Isopropyl acetate	$(CH_3)_2CH\ COOCH_3$	26
Acetone	CH_3COCH_3	122
Methanol	CH_3OH	80
Allyl alcohol	$CH_2:CHCH_2OH$	20
Butyl acetate	$C_4H_9COOCH_3$	52
Butyraldehyde	C_3H_7CHO	106
Methyl isobutyl ketone	$CH_3COCH_2(CH_3)_2$	12
Morpholine	$O:(CH_2CH_2)_2:NH$	2
Dypenol SED	Polyhydric alcohols and cresylates	39
Ethylene glycol	$HOCH_2CH_2OH$	16
Extender No. 31	Mineral spirits	8
Formopon	$NaHSO_2 \cdot HCHO \cdot 2H_2O$	27
Glucono delta lactone	Delta lactone of gluconic acid	52
Inhibitor M	Ethylene diamine tetra acetic acid	26
Iversol	Soap, solvent, and penetrant blend	60
Rhyozyme LA	Diastatic enzyme	22
Serizyme	Proteolytic enzyme	22

[1] Per cent B.O.D. is based on weight of chemical; for example, 140 per cent B.O.D. indicates that each pound of chemical will exert 1.4 lb. of B.O.D.

TABLE VII—Process Chemical B.O.D.—(Continued)

Chemical		B.O.D. (%)[1]	Chemical		B.O.D. (%)[1]	Chemical		B.O.D. (%)[1]
Name	Composition		Name	Composition		Name	Composition	
Rapidase M	Diastatic enzyme	2	Succinic acid	$HOOC(CH_2)_2COOH$	48	Diethylketone	$C_2H_5COC_2H_5$	100
Soluol	—	64	Fumaric acid	$HOOC(CH)_2COOH$	61	Ethanolamine	$NH_2\ CH_2\ CH_2\ OH$	78
Syton W-20	Colloidal silica	0	Maleic acid	$HOOC(CH)_2COOH$	38	p-toluidine	$CH_3C_6H_4NH_2$	154
Tallow	Tallow	162	Maleic acid	$(CH)_2\ C_2O_3$	50	o-toluidine	$CH_3C_6H_4NH_2$	143
Vel	Sulfated monoglyceride of coconut fatty acids	27	Tartaric acid	$HOOCCHOHCHOHCOOH$	30	Acrylonitrile	CH_2CHCN	70
Diastofor L	Amylolytic, proteolytic enzyme mixture	2	Citric acid	$CH_2COOH\ C(OH)COOH\ CH_2COOH$	40	Polyacrylonitrile	$(CH_2CHCN)_x$	4
Diethylene glycol	$O(CH_2CH_2OH)_2$	4	Sodium citrate	Sodium salt of above	37	Sucrose	$C_{12}H_{22}O_{11}$	69
Leucophor	—	33	Undecylenic acid	—	54	Lactose	$C_{12}H_{22}O_{11}\cdot H_2O$	57
Oxalic acid	$H_2C_2O_4\cdot 2H_2O$	14	Sodium oleate	$C_{17}H_{33}COONa$	136	Dextrin	$(C_6H_{10}O_5)_x$	45
Pine oil	Pine oil	108	Sodium benzoate	C_6H_5COONa	125	Cellulose	$(C_6H_{10}O_5)_x$	15
Kalex	Sodium salt of ethylene diamine tetra acetic acid	2	Phthalic acid	$COOH\cdot C_6H_4\ COOH$	106	Alpha-cellulose	$C_6H_{10}O_5$	78
Hydroxyammonium sulfate	$(NH_3OH)_2SO_4$	4	Phthalic anhydride	$C_6H_4\ CO(O)CO$	106	Methylcellulose	—	1
Facid CE	—	20	Sulfanilic acid	$C_6H_4(NH_2)SO_3H$	111	Ethyl ether	$C_2H_5\ O\ C_2H_5$	3
Stantex FG	—	20	Toluene sulfonic acid	$C_6H_4(CH_3)SO_3H$	0	Diethyl ether	$C_2H_5\ O\ C_2H_5$	0
Immersol Supra	Alkylarylpolyether	2	Anthraquinone sulfonic acid	$C_{14}H_7O_2\cdot SO_3H\cdot 3H_2O$	0	Methylcellosolve	Ethylene glycol monomethyl ether	110
Hycar L	—	2	Tannic acid	—	38	Dioxane	$O\ (CH_2)_4\ O$	0
Fabrisec AA	—	44	Isopropyl alcohol	$(CH_3)_2CHOH$	133	Gasoline	—	8
Unipen	—	40	n-butyl alcohol	$C_2H_5CH_2CH_2OH$	157	Kerosene	—	53
Zelex DX	—	2	n-amyl alcohol	$CH_3(CH_2)_3CH_2OH$	155	Benzene	C_6H_6	120
Zelex DP	—	9	Iso-amyl alcohol	$(CH_3)_2CH\ CHOH\ CH_3$	156	Toluene	$C_6H_5CH_3$	0
Propionic acid	C_2H_5COOH	78	Cyclohexanol	$(CH_2)_5CHOH$	8	Xylene	$C_6H_4(CH_3)_2$	0
Sodium propionate	C_2H_5COONa	50	Octyl alcohol	$CH_3(CH_2)_6CH_2OH$	109	Naphthalene	$C_{10}H_8$	0
Butyric acid	C_3H_7COOH	84	Ethylene glycol	$HOCH_2\cdot CH_2OH$	70	Chloroform	$CHCl_3$	0
Valeric acid	C_4H_9COOH	106	Diethylene glycol	$(HOCH_2CH_2)_2O$	2	Carbon tetrachloride	CCl_4	0
Nonylic acid	$CH_3(CH_2)_7COOH$	59	Triethylene glycol	$(CH_2CH_2OH)_2\ OCH_2CH_2O$	50	Nitrobenzene	$C_6H_5NO_2$	0
Palmitic acid	$C_{15}H_{31}COOH$	107	Tetraethylene glycol	—	50	Ortho-cresol	$C_6H_4(CH_3)OH$	164
Stearic acid	$C_{17}H_{35}COONa$	144	Polyethylene glycol	$(HOCH_2\cdot CH_2OH)_x$	19	Meta-cresol	$C_6H_4(CH_3)OH$	170
Sodium oxalate	$Na_2C_2O_4$	11	Benzyl alcohol	$C_6H_5\ CH_2OH$	155	Para-cresol	$C_6H_4(CH_3)OH$	144
Lactic acid	$CH_3CHOH\ COOH$	72	Acetaldehyde	CH_3CHO	127	Beta-naphthol	$C_{10}H_7OH$	179
			Benzaldehyde	C_6H_5CHO	150	Glycine	$NH_2\ CH_2\ COOH$	54
			Methylethylketone	$CH_3COC_2H_5$	214	Glutamic acid	$HOOC\ CHNH_2\ CH_2CH_2\ COOH$	50

[1] Per cent B.O.D. is based on weight of chemical; for example, 140 per cent B.O.D. indicates that each pound of chemical will exert 1.4 lb. of B.O.D.

B.O.D. carriers necessary for proper dyeing (14). It will be noted that these carriers are used in amounts of 6 to 40 per cent OWF, compared to 1 to 3 per cent used in dyeing other fibers. In addition, acetic acid is usually used to regenerate these compounds from the alkalinity used to disperse the carriers in the bath. Ortho-phenyl phenol is commonly used for Orlon dyeing and total B.O.D. loads of 170 to 180 lb. are produced when used as outlined. The ortho-phenyl phenol and the acetic acid used to regenerate it produce 91 per cent of the B.O.D. If phenyl methyl carbinol, salicylic acid, or benzoic acid are used, the B.O.D. loads will be increased to 490 to 700 lb. These pollution loads are the highest from any textile processing and will cause severe pollution problems if any appreciable amount of cloth is processed with these three carriers.

Monochlorobenzene (3 per cent B.O.D.) has been successfully used as a carrier, but its toxicity represents a health hazard to personnel (14). If it could be used, B.O.D. loads would be reduced sharply to only 30 to 50 lb. per 1,000 lb. of cloth. Its use with enclosed systems and adequate fume hoods should be considered when pollution is a problem. Recovery of the monochlorobenzene should also be investigated.

The results indicate, therefore, that relatively low B.O.D. loads of 30 to 80 lb. per 1,000 lb. of cloth are produced in scouring rayon, Nylon, and acetate, whereas Orlon may produce 100 to 150 lb. Loads from the processing of Dacron are expected to be extremely high (at 175 to 800 lb.), depending on the carrier used. Use of monochlorobenzene may sharply reduce these to approximately 50 lb. The phenolic compounds used in Orlon and Dacron finishing are expected to cause considerable taste and odor problems on streams used for fishing and drinking water supply.

TABLE VIII.—B.O.D. Reductions Through Chemical Coagulation

Chemical	B.O.D. Reduction (%)
Soap[1]	90
Phenol	0
Glucose	0
Starch	57
Gelatin[1]	65
Glue[1]	33
Emulsifiable mineral oil	80
Sulfonated castor oil	82
Sulfonated vegetable oil	44
Coconut oil[1]	92
o-phenyl phenol	0
Salicylic acid	17
Benzoic acid	8
Acetic acid	8
Oxalic acid	86
Sodium acetate	0
Alum-wax emulsion	85

[1] Required more than 3 lb. of alum per 1,000 gal.; soap 5 lb., gelatin 18 lb., glue 5 lb., coconut oil 10 lb.

The B.O.D.'s of some of the chemicals used in processing synthetic fibers are recorded in Table VII. In addition, the B.O.D. reductions obtained on treating some of the textile chemicals are indicated in Table VIII. In these treatments 1,000-p.p.m. solutions were treated with 3 lb. of alum per 1,000 gal. and enough lime to regulate the pH to 6 to 8. If no flocculation occurred, alum dosage was increased until flocculation did occur. It will be noted that good reductions were obtained on treating soap, emulsifiable mineral oil, sulfonated castor oil, coconut oil, oxalic acid, and alum-wax emulsion. Fair reductions were obtained with starch, gelatin, and sulfonated vegetable oil. Gelatin, however, had to be treated with 18 lb. of alum before precipitating, indicating that this compound may cause trouble in waste treatment plants which use chemical coagulation.

Very poor reductions were obtained with phenol, glucose, glue, o-phenyl phenol, salycilic acid, benzoic acid, acetic acid, and sodium acetate. It will be noted that most of the carriers for

Orlon and Dacron dyeing are in this group, consequently chemical coagulation should not prove satisfactory for treatment of such wastes. Laboratory experiments on Orlon scour and dye wastes indicated that reductions of only 20 to 50 per cent could be obtained. Biological oxidation or recovery must therefore be used for such wastes if treatment is necessary.

Summary of Pollution Sources and Loads

A summary of pollution loads obtained from the surveyed mills is recorded in Table IX. These results show that the processing of grease wool and Dacron (when using benzoic acid, salicylic acid, or phenylmethylcarbinol) produce the greatest B.O.D. loads, averaging 400 to 800 lb. per 1,000 lb. of cloth. Cotton, Orlon and Dacron (with ortho-phenyl phenol) are next in order, averaging 125 to 250 lb. per 1,000 lb. of cloth. Rayon, acetate, Nylon and Dacron (with monochlorobenzene) produce the lowest loads, averaging 35 to 80 lb. per 1,000 lb. of cloth. If the cloth is to be waterproofed, B.O.D. loads of 20 to 40 lb. per 1,000 lb. of cloth should be added to these values.

TABLE IX.—Expected Pollution Loads from Scouring and Dyeing of Various Textile Fibers[1]

Fiber and Chemical	Quantity (gal.)[2]	B.O.D.	
		(lb.)[2]	(p.p.m.)[3]
Rayon	5,000	50–80	1,200–2,000
Acetate	9,000	40–60	500–800
Nylon	15,000	35–55	300–500
Orlon	25,000	100–150	500–700
Dacron:			
o-phenyl phenol	12,000	150–250	1,500–2,500
Monochlorobenzene	12,000	30–50	300–500
Benzoic acid	12,000	600–800	6,000–8,000
Salicylic acid	12,000	500–700	5,000–7,000
Phenylmethylcarbinol	12,000	400–600	4,000–6,000
Cotton	70,000	125–250	200–600
Wool (grease)	70,000	400–600	700–1,200

[1] Results are estimates from actual mill surveys, except for Dacron.
[2] Per 1,000 lb. of cloth.
[3] Average for the equalized waste.

The approximate water consumption and B.O.D. of the equalized wastes are also listed to indicate the relative volumes and B.O.D. concentration in the effluents.

The surveys indicated that B.O.D. loads from these mills are produced from two main sources—the "natural" impurities in the fibers and the process chemicals used to weave and process the cloth. These are further broken down into the following subdivisions:

1. "Natural" impurities in the fiber which must be removed to insure proper processing.
2. Antistatic, lubricating, carding, or sizing agents needed for weaving.
3. Scouring agents required to remove the previous two constituents.
4. Emulsifying, dispersing, penetrating, wetting, leveling, acidifying, oxidizing, reducing, and carrying agents needed for dyeing, bleaching, or printing.
5. Special finishing agents needed for waterproofing, mildew-proofing, fireproofing, softening, etc.

A breakdown of these sources and the range of B.O.D. loads expected from these subdivisions is given in Table X. These ranges are based on the surveys and on processing methods and chemicals suggested in the textile processing literature. The lower B.O.D. loads are calculated on the basis of use of low-B.O.D. chemicals and processing methods. The ranges indicate the reasons for the extreme variability noted so often in textile waste investigations.

Pollution Reduction Program

The results of these studies indicate conclusively that adequate reduction in B.O.D. loads may be obtained through substitution of low-B.O.D. chemicals for the high-B.O.D. chemicals normally used. The most important substitutes noted so far are synthetic detergents for soap; ammonium

TABLE X.—Estimated Pollution Load Ranges from the Processing of Various Fibers (Pounds of B.O.D. per 1,000 Lb. of Cloth)

Fiber	"Natural" Impurities	Sizes, Oils, Antistats	Scouring	Dyes, Emulsifiers, Carriers, Etc.	Special Finishes, Waterproof, Etc.	Total
Cotton	30–50	5–100	5–60	2–80	2–80	44–370
Greasy wool	200[1]–300	2–90	15–150[2]	5–100	2–80	219[1]–720
Scoured wool	10–20	2–90	10–150[2]	5–100	2–80	29–440
Rayon	3–7	5–60	5–50	2–50	2–80	17–247
Acetate	3–7	5–60	5–50	2–50	2–80	17–247
Orlon	3–7	5–60	5–50	5–100	2–80	20–297
Nylon	3–7	5–60	5–50	2–50	2–80	17–247
Dacron	3–7	5–60	5–50	30–600	2–80	45–787

[1] If grease and suint are removed by solvent extraction this load may be reduced to approximately 20 lb.

[2] High value includes soap used for fulling also.

sulfate for acetic acid; carboxymethylcellulose and hydroxyethylcellulose for starch; polyvinyl alcohol, polyacrylic acid, and styrene-base sizes for gelatin; and monochlorobenzene for o-phenyl phenol; etc.

These important substitutes were found despite the limited scope of these surveys and the limited knowledge of the investigators on textile processing methods. Many more important substitutes undoubtedly will be found if the textile industry itself will survey its process chemical inventories and determine the B.O.D.'s of the chemicals most widely used. With such a master list the pollution potential of any process or mill may be readily determined and modified to use low-B.O.D. substitutes wherever possible. The nucleus of such a list (Table VII) has been started by the New England Interstate Water Pollution Control Commission studies at Wesleyan University and the University of Rhode Island (15) and has been considerably broadened by the work of Stafford and Northup (16), Mills and Stack (17), Heukelekian and Rand (18), Bogan and Sawyer (19); and Lamb and Jenkins (20).

To do this as thoroughly and expeditiously as possible, it is suggested that a full-time research group directed by a committee of textile chemists, sanitary engineers, and chemical manufacturers should be set up by the textile industries to gather these data. Such a group would be able to render valuable aid quickly to plants faced with pollution problems. In addition, continuing research could be carried out on problems which are not now solvable by such a procedure.

Such problems would probably involve kier or continuous scouring wastes, wool grease and suint wastes, wash after soap-fulling wastes, and Dacron and Orlon dye wastes. Chemical oxidation of the hot kier liquors, including the use of catalysts, should be investigated. Wool grease and suint recovery by means of methyl-isopropyl alcohol solvent method should be explored. But more important, markets for the recovered grease and suint should be developed.

Acid fulling should be re-evaluated and used wherever possible. If soap fulling is necessary, package treatment plants using alum coagulation could be designed to treat the segregated soapy wastes. Solvent recovery of the large amounts of expensive carriers in Orlon and Dacron wastes should be investigated. In addition, economical segregating, equalizing, and heat-exchanging systems should be developed for both old and new mills. In many

instances, equalization alone may solve a pollution problem.

Basic research on B.O.D. should be carried on, particularly to determine which organic structures are resistant to bacterial attack. Chemical manufacturers may use these data to modify their chemicals so as to produce low-B.O.D. products. Low-B.O.D. emulsifying, leveling, and wetting agents are particularly needed by the textile industry.

Research work on the effect of such oxidizing agents as hydrogen peroxide, peracetic acid, sodium perborate, chlorine dioxide, etc., on textile wastes and on streams should be undertaken, inasmuch as these are being used in increasing amounts by the textile industry.

All the data so far encountered indicate that the possibilities of substantial pollution reduction, through the substitution methods outlined, are very bright indeed. It is expected that the textile industry as a whole can quickly reduce its pollution load by 40 to 60 per cent through the substitutions noted. Over a longer period of time reductions of 70 to 90 per cent should be obtained. Many treatment plants now considered necessary will not have to be built if such a program is successful, or certainly the size of the treatment plant will be considerably reduced. In view of the large net return through such savings, the textile industry should underwrite such a program as soon as possible. The savings from only one large treatment plant can finance such a research program for many years.

Since this pollution reduction is simple and economical, pollution regulatory agencies should not hesitate to issues orders to abate pollution.

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DISCUSSION

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The concept of process chemical changes to bring about a reduction in the total B.O.D. of textile wastes as set forth by Masselli and Burford offers a partial solution to the over-all waste problem. At the same time, it creates new problems which must be considered and answered satisfactorily before process chemical changes are made. Examination of the proposed changes in the cotton finishing processes indicated that substitution of carboxymethylcellulose for starch; synthetic detergents for soaps; ammonium sulfate, diammonium phosphate, or sulfuric acid for acetic acid; and peroxide bleach for hypochlorite bleach, would result in a total B.O.D. reduction of 50 to 80 per cent.

The first problem which must be answered is whether or not these new compounds have a lower "true" B.O.D. or merely a lower "apparent" B.O.D. The standard 5-day B.O.D. test used so widely as a measure of organic strength and as a measure of oxygen demand in a stream is not a satisfactory test for either of these two items when considering many industrial wastes. The microorganisms used for seed in the standard B.O.D. test are sewage microorganisms which have resulted from the metabolism of the simple carbohydrates and amino acids in sewage. The microorganisms are not necessarily adapted to the many complex natural and synthetic compounds occurring in industrial wastes. Use of these sewage microorganisms in the standard 5-day B.O.D. test will show slow B.O.D. values for all organic compounds but the simple carbohydrates, amino acids, and related compounds in the over-all metabolic pathway. Yet, if these sewage microorganisms are placed into solutions containing the complex and unusual compound, they develop the necessary biochemical mechanisms to utilize the compound. This process of adaptation is very important in the biological stabilization of industrial wastes. Adaptation will occur in the receiving body of water; therefore, it is important that adapted seed be used rather than sewage seed when considering industrial wastes.

It is possible to predict the metabolic potential of any given organic compound from its chemical structure and the fundamental knowledge of the biochemistry of microorganisms. Carboxymethylcellulose (CMC) has a resistant chemical structure, but not a completely resistant structure. The rate of biological degradation of CMC would be much slower than starch, as adaptation to CMC would delay the over-all metabolism. The presence of more readily available organic matter would probably result in further delay in CMC oxidation. The major problems in the use of CMC from the textile manufacturers are the high cost of CMC as compared to starch, a slightly inferior finish, and the natural resistance to change.

Synthetic detergents have some biologically resistant forms and some nonresistant forms. The term "synthetic

detergents" is too broad a term to use when discussing biological degradation. It is even impossible to break synthetic detergents down into their three major classes—cationic, nonionic, and anionic —and to consider only these classes. Biological degradation of synthetic detergents can be discussed intelligently only when the particular chemical structure of the particular detergent is known. Even the term "alkylbenzenesulfonate (ABS), which has been used so often in literature to designate the resistant types of anionic synthetic detergents, is too broad a term, as there are many different alkylbenzenesulfonates. Most of the synthetic detergents being manufactured today are not readily metabolised by sewage bacteria and require some adaptation for rapid metabolism. Adaptation to synthetic detergents will reduce the rate of oxidation the same as with CMC.

Cotton finishing wastes are normally deficient in nitrogen and phosphorus. If the receiving body of water does not have sufficient excess of nitrogen and phosphorus, the rate of stabilization of the wastes will be delayed in proportion to the nutritional deficit. The standard B.O.D. test supplies sufficient nitrogen and phosphorus for maximum stabilization. Therefore, it is quite possible that the 5-day B.O.D. obtained in the laboratory may give a completely erroneous value with regard to that which will occur in the receiving body of water. For this reason, it is best to determine the optimum B.O.D. by using supplemented water and to determine the actual rate of oxygen depletion by using water from the receiving stream or lake for dilution. It may well be that the rate of metabolism of the organic compounds left in many instances would be sufficiently slow that no additional treatment would be required.

Substitution of ammonium sulfate or diammonium phosphate for acetic acid would result in the removal of one of the most readily available organic sources, but would tend to reduce the nutritional deficiency. It is possible that the increased rate of degradation of the remaining organic matter could create a more acute problem. The use of synthetic detergents will increase the over-all phosphorus content of the wastes. If an excess of nutrients existed, an algae problem could result if the receiving body of water was a lake or flowed into large stagnant reaches.

Another aspect of the over-all problem is the ultimate fate of these slowly metabolized compounds. It is impossible to speculate on this factor too much, because every mill will pose its own separate problem. But the question of the effect of the resistant compounds in the receiving body of water must be answered. Are these compounds toxic to higher animals? Can they be safely ingested over long periods of time without building up in some vital organ of the higher animals? Do they increase the cost of treatment of the water for either drinking water or for industrial process water farther downstream? An answer of "yes" to any of these questions could prevent the use of these chemical substitutes. The one good thing about high-B.O.D. compounds is that they are readily broken down by microorganisms in the receiving body of water and cannot persist too long.

After careful consideration of all of these factors, there will be some mills which can use the substitutes satisfactorily and others which cannot. Many of the mills which cannot make the process chemical changes will be forced to treat their wastes either in part or totally before they can satisfactorily be discharged to the receiving body of water. A small cotton finishing mill in New Jersey was faced with a court order to stop polluting the adjacent stream with their waste waters. The variable nature of their strong wastes and the high cost of conventional bio-

logical treatment systems forced the industry to consider going out of business unless a new, more economical treatment system could be developed. To meet the needs of this mill, a modification of activated sludge was set up to solve the following problems:

1. Variation in organic strength.
2. Variation in waste flow.
3. Variation in pH.
4. Low capital cost.
5. Low operating cost.
6. Simplicity of operation.
7. No excess sludge.

Cotton Waste Treatment Plant

The modified activated sludge system was designed to treat the strong wastes only from the desizing and caustic wash operations. The average analyses of the wastes on which the plant was designed were as follows:

Volume (g.p.d./7-day week)	100,000
pH	11.4
5-day B.O.D. (p.p.m.)	950
Total Warburg oxygen demand (p.p.m.)	1,160
Phosphorus (p.p.m.)	2.0
Total nitrogen (p.p.m.)	24

The treatment plant consisted of a lagoon and the biological treatment unit. The lagoon is used to level out the variation in flows, because all of the wastes are produced during a single shift, five days a week. The wastes are continuously pumped 24 hr. a day, seven days a week from the lagoon to the treatment unit proper. The biological treatment plant is a large tank divided into four sections, each 20 by 30 ft. Each section is divided longitudinally into two compartments by a wooden baffille. One compartment is the aeration compartment and the other is the settling compartment.

The wastes flow into the aeration tank along one side and are instantaneously mixed with the entire contents of the aeration tank. The organic content of the entire aeration compartment is constant and is kept low by a long period of aeration. The wastes are diluted with such a large volume of mixed liquor that fluctuations in waste strength produce only slight changes in the aeration tank. The pH of the raw wastes is neutralized by the carbon dioxide produced in the metabolism of the organic matter and no preliminary neutralization is required.

The activated sludge is separated from the liquid phase in an upflow sedimentation unit in which the sludge is returned to the aeration tank by gravity, thereby eliminating the need for mechanical sludge return equipment. Operating on endogenous metabolism, the excess sludge is burned up by aerobic stabilization. Because the entire quantity of organic matter must be oxidized, the aeration unit was designed for a maximum oxygen transfer by diffused aeration of 40 p.p.m. of oxygen per hour, with total oxidizable organic matter based on the chemical oxygen demand of the waste rather than on the 5-day B.O.D.

The only operating expenses are connected with pumping the wastes to the treatment plant, compressing the air, and one man-hour per day for analyses and maintenance. The total capital investment was estimated at $25,000. One-fourth of the plant has been completed and put into operation to test the basis of design and operating characteristics.

The plant was seeded with a large quantity of domestic sewage activated sludge and put into full operation. After only six days operation the effluent had a B.O.D. of 10 p.p.m. from a raw waste of 368 p.p.m. B.O.D. and 1,160 p.p.m. oxygen consumed.

The simplicity of design and operation has been borne out in the initial results. Tests are being conducted to determine the maximum load that can be placed on the unit and to determine the rate of oxygen demand and transfer. Although it is still a little early to say definitely, it appears that this

modification of activated sludge is well suited, both economically and operationally, to small cotton textile mill waste problems.

Complete elimination of a waste discharge is the only positive solution to industrial waste problems. But this is impossible in most cases. The concept of process chemical substitution can reduce the rate of B.O.D. in the receiving body of water in many cases, but poses the problem of the ultimate fate of the resistant compound. For those cases where biological treatment is required, a modification of activated sludge has been proposed.

AUTHORS' COMMENT

In reference to the "true" B.O.D. of process chemicals it should be noted that some chemical compounds have low "true" B.O.D.'s whereas others have high B.O.D.'s. Synthetic chemists can synthesize chemicals with the desired processing characteristics and low "true" B.O.D.'s if they will direct their energies in this connection. The important thing is that the textile industry recognize this and attempt to find those chemicals which are desirable from a processing and pollution reduction point of view.

The use of phosphates as builders for detergents is well recognized as a potential cause of trouble through algal blooms. Other builders, however, are available and could be used.

The ultimate fate of any compound is, of course, important and new ones must be continuously checked to determine whether they or their degradation products will cause trouble. Eventually research should find compounds which will be satisfactory on all counts.

The description of Prof. McKinney's cotton waste treatment plant is extremely interesting and preliminary results indicate that it is the closest thing to a fool-proof, low-cost package treatment unit so badly needed by the textile and other industries for waste treatment. Its adaptability to the highly alkaline cotton wastes appears excellent and the low effluent B.O.D.'s are encouraging. It is hoped that these preliminary results will lead to future studies and the application of the data obtained.

FORD APPOINTED DIRECTOR BDSA

Richard V. Ford, Vice-President and Export Manager of the Ford Meter Box Company, Wabash, Ind., was appointed on August 24, 1956 as Director, Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, U. S. Department of Commerce. Under the rotation system, outstanding business executives serve the Government without compensation for periods of six months or longer. Mr. Ford succeeds Louis F. Frazza, executive of the Johns-Manville Sales Corp., who has served since March 1956.

Mr. Ford is a member of several professional organizations in the water works industry. He is Vice-President elect of the Water and Sewerage Works Manufacturers Associations.

WASTE TREATMENT AT AN AUTOMOBILE ASSEMBLY PLANT *

By Edward R. Grich

Superintendent, Waste Treatment, Ford Motor Company, Mahwah, N. J.

The Ford Division of the Ford Motor Company recently completed the transfer of its assembly plant facilities at Edgewater, N. J., to larger quarters at Mahwah, N. J. This new plant is located on a 177-acre site and contains an assembly building covering 39 acres.

Having a plant of this magnitude locate within its boundaries undoubtedly results in financial benefits to a municipality. However, many problems could arise if the industry chose neither to recognize nor accept its responsibilities to the municipality. Certainly, one of these responsibilities is the satisfactory disposal of the sanitary and industrial wastes coming from the factory. The location of this plant on a stream having a Class A classification, in an area of established recreational uses, serves to intensify this responsibility.

Receiving Waters

The receiving stream of the Ford-Mahwah assembly plant wastes is the Ramapo River, long noted for its scenic beauty and the recreational facilities it affords. It flows through the Ramapo Mountains, and discharges into a lake region that is utilized for bathing and fishing. In addition, it is used as a raw water source for a potable water supply by the Passaic Valley Water Commission. This agency obtains its water from the Passaic River into which the Ramapo River eventually flows. In 1950, the New Jersey Water Policy and Supply Council granted the North Jersey District Water Supply Commission diversion rights to the Ramapo River. This project was completed December 1953 and pumping was started the same month. The Commission may draw water from this river from October through May, providing the flow is greater than twice the normal dry weather flow. Three regulatory agencies, then, maintain a close check on the condition of the river: the Council, the Commission, and the State Department of Health.

The officials of Ford-Mahwah recognize the necessity of maintaining a high degree of treatment of plant wastes to satisfy the requirements of these agencies. In addition, they recognize and accept their responsibility to the other stream users. Every effort is made to abate pollution of this river and still produce the benefits that normally accrue from industrial operations. With this in mind, two treatment plants were installed at the plant site; one to treat the sanitary wastes and one to treat industrial wastes.

Sanitary Waste Treatment System

The sanitary waste treatment plant provides secondary treatment through the use of a rotary distributor-type trickling filter. It is designed to handle a maximum flow of 550 g.p.m. or 20 m.g.a.d. Facilities are provided (Figure 1) for coarse screening, primary sedimentation, oxidation, secondary sedimentation, postchlorination, and separate sludge digestion. Facilities for prechlorination and chlorination prior to secondary settling are also available for use if needed.

* Presented at the 1956 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 14–16, 1956.

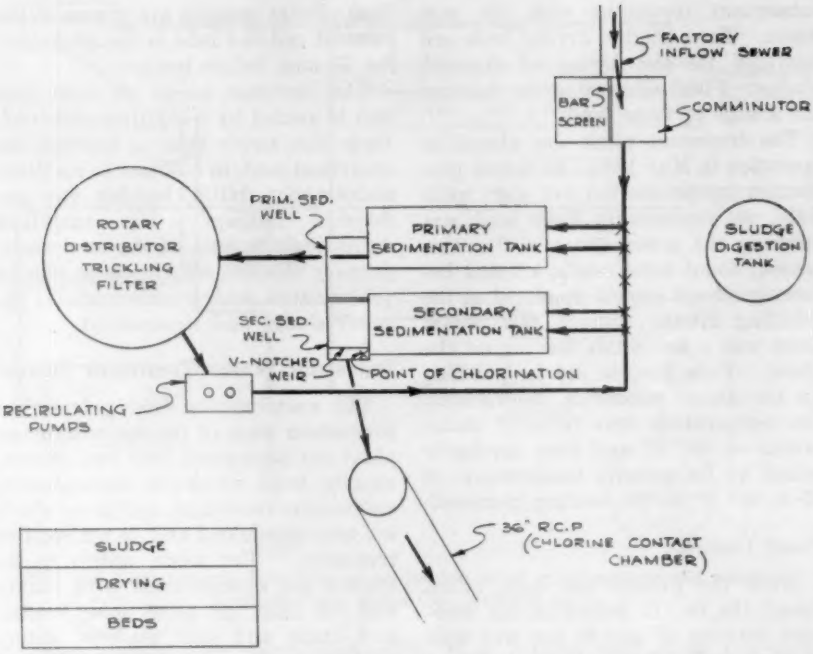

FIGURE 1.—Schematic flow diagram of the sanitary waste treatment plant, Ford Motor Co., Mahwah, N. J.

Operating Procedures

Prior to starting the flow through the plant, the trickling filter distributor arms, all underwater piping and columns, and other metal structures were coated with a rustproofing compound as a preventive measure against corrosion.

The piping was arranged so that both the primary and secondary sedimentation tanks could be utilized for primary sedimentation only, by merely opening one valve, should there occur any need for plant expansion. Following primary sedimentation, the waste enters a two-compartment chamber interconnected with a float-operated, butterfly valve. One compartment contains the effluent from the primary settling unit; the other that from the secondary settling unit. The purpose of this chamber is to maintain a constant dosing rate on the trickling filter. When the plant influent is inadequate in quantity for the preset dosing rate, sufficient secondary sedimentation tank effluent is allowed to pass through the butterfly valve to make up the deficit. Two 275-g.p.m. recirculating pumps are used to return the trickling filter effluent to the final settling tank. The final effluent, after chlorination, passes into a 36-in. outfall sewer line which serves as the chlorine contact chamber. A detention time of approximately 30 min. is obtained in this line.

Sludge Digestion

The sludge digestion tank has a floating cover and is equipped with an external heat exchanger. Four supernatant selector valves are available, in addition to a supernatant overflow line which discharges the displaced supernatant to the influent end of the primary sedimentation chamber for

subsequent treatment with the raw waste. Three sludge drying beds are provided for the drying of digested sludge. Final disposal is by hauling the sludge to farm land.

The treatment plant was placed in operation in May 1955. As actual production operations did not start until July, an exceedingly light load was entering the sewer system. For this reason, about seven weeks elapsed before significant growth appeared on the trickling filters. During this period there was a low solids loading on the plant. Therefore, to aid in building up the sludge volume in the digester, the temperature was initially maintained at 80° F. and then gradually raised to its present temperature of 90 to 95° F. as the loading increased.

Plant Control

Since the process has been established, the B.O.D. reduction has averaged between 85 and 90 per cent with an average B.O.D. in the final effluent before chlorination of less than 20 p.p.m. The flow, based on 24 hr., normally averaged approximately 95 g.p.m. when one 8-hr. shift operation was employed. However, in January 1956, a second 8-hr. shift was started which served to increase the average flow to approximately 110 g.p.m.

Complete control analyses are performed by the plant operator in a modern, well-equipped laboratory. The laboratory is provided with ample bench space, an abundance of storage space for equipment and chemicals, and sufficient modern equipment to permit the operator to determine his control analyses with a maximum of accuracy and a minimum of inconvenience. A tap for drawing chlorinated effluent samples was installed in order that the operator did not have to climb into the influent end of the outfall sewer manhole to draw this sample. Since a fence and 10 railroad tracks separate the plant from the discharge end of the outfall sewer, the final effluent samples are drawn at the influent end and held in the laboratory for 30 min. before testing.

The operator works an 8-hr. day and is guided by a schedule which affords him ample time to perform his analytical work in addition to his plant maintenance duties, barring any unforeseen mishaps. His analytical duties include tests of the raw waste, primary clarifier effluent, final effluent (chlorinated and unchlorinated), digester sludge and supernatant.

Industrial Waste Treatment System

The waste waters coming from the production areas of the manufacturing plant are segregated into two groups, namely, those which are contaminated and require treatment, and those which are uncontaminated and do not require treatment. The waste waters to be treated are contaminated with paints and oils from the paint spray booths and chain and skid washers, detergents from the washmobile and paint spray booth air wash, caustic from the chain and skid washers, and hexavalent chromium from the phosphate coating machines.

The coating machines prepare the metal parts for painting and entail six stages of operation. The first stage is a cleaning operation which produces an alkaline waste containing detergents and complex phosphates. Stages two and three are water rinses following the cleaning operation. These rinse waters are essentially uncontaminated and do not enter the treatment system. In stage four, the metal is etched and zinc ions are deposited to act as a binder. The wastes are contaminated with zinc and phosphate ions. However, this waste is treated at the etching machine and does not enter the industrial waste treatment system. Stage five is a water rinse following the stage four operation and this rinse water is not diverted into the treatment system. In stage six, the chemical reaction which

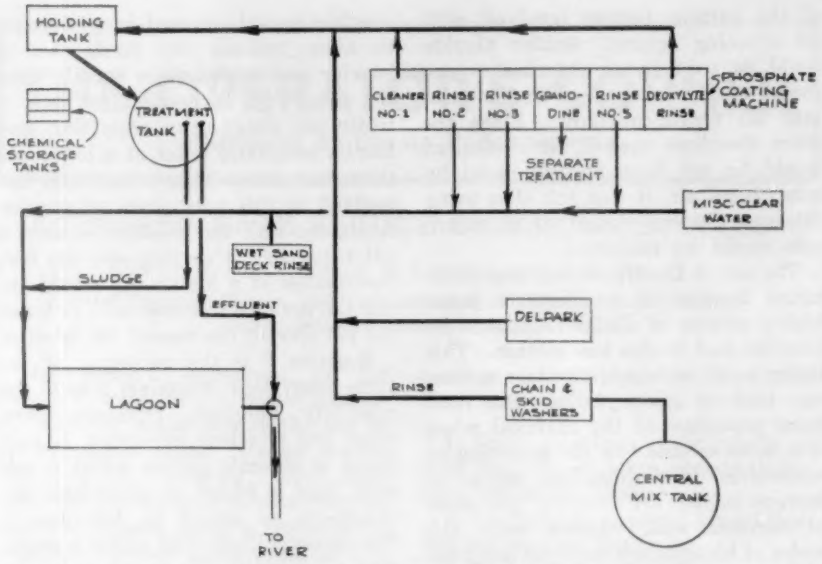

FIGURE 2.—Schematic flow diagram of the industrial waste sources and treatment facilities, Ford Motor Co., Mahwah, N. J.

has taken place in stage four is neutralized and the waste water coming from this operation contains chromic and phosphoric acids.

The uncontaminated waste waters are comprised of the aforementioned water rinses, cooling waters, and the wet sand-deck rinse water. This latter rinse water, which is sprayed on the car bodies after the primer paint coat has been rubbed, is contaminated with a small amount of primer paint but it is in the form of particles having a high specific gravity and can be readily settled, yielding a clear uncontaminated water.

Waste Water Treatment

The contaminated waste waters flow into a holding tank from where they are drawn off into a batch-type treatment tank. The uncontaminated waters flow directly into a lagoon to effect settling, after which they flow into the receiving stream. Figure 2 is a schematic drawing of the industrial waste sources and the treatment facilities.

It is evident that there are three major objections to the composition of this waste, namely, the pH, the paint solids, and the hexavalent chromium.

The hexavalent chromium is treated in two consecutive flocculations, the first to clarify the waste and the second to reduce the hexavalent chromium to its trivalent ion prior to precipitating it with lime. Sufficient ferric chloride and sulfuric acid (the amount being predetermined by laboratory tests) are added to the waste in the treatment tank by the use of compressed air and then rapidly mixed for a short period of time to evenly distribute the chemicals throughout the waste. This mixture is then flocculated for 10 to 15 min. Since the precipitation of chromium necessitates first reducing the hexavalent chromium to its trivalent state, a reducing agent must be employed.

Reducing Agent

The reducing agent, sodium metabisulfite, was chosen after evaluation

of the various factors involved with all reducing agents. Sulfur dioxide could be used but a chlorinator-type feeder is required to feed the material into the treatment tank. Since the other chemicals used in the treatment would be fed from storage tanks by compressed air, it was felt that using this same feeding system for all chemicals would be preferred.

The use of ferrous sulfate was eliminated because it produces a much higher volume of sludge than does the bisulfite and is also less soluble. This latter point is important since a storage tank of given volume can hold more poundage of the chemical when it is more soluble. In the reduction of hexavalent chromium, six moles of ferrous sulfate are required per mole of chromic acid, whereas only 1½ moles of bisulfite are required per mole of chromic acid. Therefore, decidedly less sludge will be produced using bisulfite.

Sodium Metabisulfite Reactions

A predetermined amount of sodium metabisulfite sufficient to reduce all of the hexavalent chromium present is added to the treatment tank. As this reaction proceeds more rapidly at low pH values, enough sulfuric acid is added to reduce the pH below 3.0. This mixture is then stirred for 10 min. prior to the addition of sufficient lime to precipitate the soluble trivalent chromic sulfate and to neutralize the waste mixture. The chemical reactions taking place in this treatment are as follows:

$$2FeCl_3 + 3Ca(HCO_3)_2 \rightarrow 2Fe(OH)_3 + 3CaCl_2 + 6CO_2 \quad (1)$$

$$2H_2Cr_2O_7 + 3Na_2S_2O_5 + 3H_2SO_4 \rightarrow 2Cr_2(SO_4)_3 + 3Na_2SO_4 + 5H_2O \quad (2)$$

$$Cr_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Cr(OH)_3 + 3CaSO_4 \quad (3)$$

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O \quad (4)$$

Reaction 1 takes place between the coagulating agent ($FeCl_3$) and the natural alkalinity in the water to form the insoluble $Fe(OH)_3$ floc. A ferric coagulating salt is used in preference to alum because the ferric floc is heavier and settles more readily than the alum floc, is precipitated over a wider pH range than alum floc, and has its isoelectric point at a lower pH than does alum. This is extremely important in this case, since subsequent treatment with the bisulfite requires a pH below 3.0. Carrying out this first flocculation at a higher pH would entail the use of additional acid to lower the pH during the second flocculation.

Reaction 2 is the reduction of the toxic hexavalent chromium ions to the relatively non-toxic trivalent state. Since the trivalent chromium is produced as chromic sulfate, which is soluble, lime is added to precipitate the chromium as shown in Reaction 3. The excess sulfuric acid which is necessary to complete this reaction, is also neutralized with lime as shown in Reaction 4. This mixture is flocculated 15 to 30 min. and allowed to settle 1 to 2 hr.

The clear supernatant is drawn off into the outfall sewer and the accumulated sludge is drained into a lagoon which also receives the uncontaminated waste waters. Settling is effected in this lagoon and the clear supernatant overflows into the outfall sewer. The lagoon is equipped with baffle plates to prevent any floating oils or grease from entering the outfall sewer, and it is periodically hand-skimmed.

Also available are four waste disposal trucks, each having a capacity of 1100 gal. These are portable units equipped with hoses and are used as stand-by units in the event of a breakdown of the industrial waste treatment facilities.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

INCREASED-RATE SLUDGE DIGESTION STUDIES *

BY H. R. ZABLATZKY, M. S. CORNISH, AND J. K. ADAMS

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The planned expansion of the Bergen County (N. J.) Sewer Authority facilities would double the size of the treatment plant. Recent studies (1)(2)(3)(4), however, have indicated the possibility of accelerating the digestion process, thereby reducing the required digester volume and making possible a reduction in future construction costs. This led personnel of the Bergen County facilities to a reconsideration of the ecological facts and hypotheses, as well as the physical and mechanical characteristics of sludge digestion. A decision was made to install an increased-rate sludge digestion system using the present facilities, in order to determine whether construction economies could be achieved in the expansion of the treatment plant.

Although the process now in operation is not true high-rate anaerobic sludge digestion, the rate of digestion has been accelerated to a point beyond that found in conventional practice (5). Moreover, the sludge volume requirements have been reduced by more than 25 per cent. However, due to insufficient loading levels the maximum attainable digestion rates have not yet been realized.

Theory and Concepts

According to Sawyer and Schmidt (6) there are several major shortcomings of single-stage digestion units. Their principal objections are:

1. Scum problems, particularly at high loadings or when certain industrial wastes are present.
2. Inability to produce a well-clarified supernatant liquor.
3. Thermal stratification.

Attempts to overcome the first and third problems have aggravated the problem of supernatant liquor. The authors believe that the three mentioned objections are also significant in a two-stage digestion system.

Haseltine (7), McKinney *et al.* (8), Eckenfelder and O'Connor (9), and Zablatzky *et al.* (10) have derived relationships between the microorganisms and their food supply in aerobic systems. It is reasonable to assume that a similar relationship should exist in anaerobic processes.

Buswell (11), Rudolfs and Del Querico (12), Fuhrman (3), Morgan (1), Torpey (2), and many others have investigated high-rate anaerobic digestion.

Rudolfs and Del Querico (12) reported that in the digestion of soluble organic wastes the organisms responsible are concentrated in the sludge. Since the organism must have access to the food it would seem logical to increase the contact time by keeping the sludge in motion instead of being quiescent as in the conventional digester.

* Presented at the 1956 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 14–16, 1956.

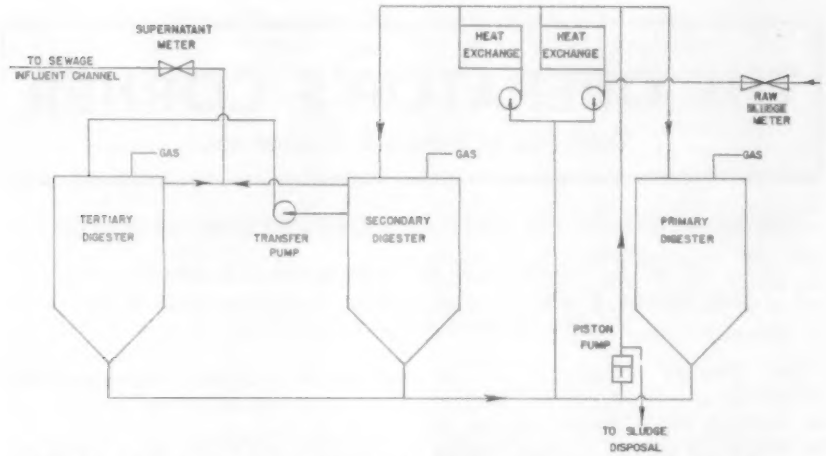

FIGURE 1.—Digester flow diagram during increased-rate sludge digestion studies.

Morgan (1) advocates adjustment of the environment to encourage intensified microbial activity for sludge stabilization. He accomplished the contact by recirculating digester gas through the sludge.

Torpey (2) accomplished the same results by maintaining a denser sludge in the reaction or primary digester which automatically increased the numbers of organisms due to the higher solids content and thus a balance was obtained between the microorganisms, buffering material, and food supply.

Buswell (11) applied a fibrous material for the mechanical support of biological life and found a rapid growth developed.

The findings of these investigators stress one theme—the proper quantity of organisms, buffering material, and food.

Digester Equipment

The equipment at the Bergen County sewage treatment plant was adaptable to conversion to a higher-rate sludge digestion process.

The sludge digestion equipment consists of four 1,200,000 gal. floating cover digesters. Each digester has gas equipment, a heat exchanger, and a centrifugal recirculation pump. The raw sludge and supernatant meters, as well as a positive displacement pump, are common to all digesters. The piping is arranged to give maximum flexibility. Figure 1 shows a schematic diagram of the piping and equipment.

Grease and bar screenings are not discharged to the digester. Grease is collected and removed by a scavenger and the bar screenings are collected and buried. A scum layer 24 to 36 in. thick has existed during the last 2½ years. Buswell (11) states that it is important to avoid the formation of a heavy scum layer in the digesters, which would form a zone of higher substrate concentration in which excessive quantities of acid are likely to develop. This acid condition would retard the destruction of organic material and utilize valuable digester space. These are the principal reasons for the exclusion of both grease and screenings from these digesters.

Another digestion aid mentioned by Schlenz (13), Buswell (11), and Rudolfs and Del Querico (12), and practiced by Hood (14), is a slow and almost continuous addition of raw sludge to the digesters. This tends to produce a uniform rate of digestion

and avoids the difficulties associated with large sludge additions which may upset the digestion process.

Both single- and two-stage digestion were tried, and both produced supernatant of poor quality with suspended solids ranging from 10,000 to 20,000 p.p.m., although the digested sludge was of a good quality and had less than 57 per cent volatile solids. A fourth digester was put in service making the system a multi-stage process with two primary, one secondary, and one tertiary or third-stage digester. The results using this sequence were excellent, and the supernatant suspended solids ranged from 600 to 2,200 p.p.m. Incidentally, the grab samples of supernatant liquor had 5-day B.O.D. values in the order of 80 to 250 p.p.m. This supernatant had no noticeable effect on the primary sedimentation or secondary processes, even when discharged at a rate of 500 to 600 g.p.m. into a raw sewage flow of 10 to 15 m.g.d.

Experimental Procedures

When considering the possibility of increased-rate sludge digestion, it was first believed that the return of methane and carbon dioxide to the digestion system would be toxic because both are bacterial end products. However, the fact that both gases are comparatively insoluble eliminated this factor. In addition, data on high-rate anaerobic digestion processes do not contain sufficient information about the factors which are necessary to bring digestion to completion with respect to total gas production. Also there is little knowledge on what is necessary for the best separation of supernatant and good digested sludge compaction. Solids reductions were computed from a table prepared by Burley (15).

Considering these factors, the raw sludge feed rate was increased from 50 to 66 per cent in one of the primary digesters. This proved to have no adverse effect on digestion and the rate was increased to 80 per cent then finally to 100 per cent.

When the raw sludge feed rate was increased the bottom sludge of the same digester was circulated with a centrifugal pump. This sludge passed through the heat exchanger, where it mixed with the raw sludge, and was then discharged to the upper portion of the digester. A positive displacement pump was needed to start circulation. Once the sludge was in motion the only difficulty encountered was a small amount of clogging in the recirculating pumps.

Samples were taken at various points in this primary digester and it was found there was insufficient heating and mixing. Utilizing another heat exchanger and additional centrifugal pumps solved these two problems. The pumps could recirculate the tank contents in less than 24 hr., thus satisfying the ecological and physical requirements.

The solids concentration in the primary digester was maintained at 2.5 per cent or higher by recirculating bottom sludge from the secondary and tertiary digesters back to the primary digester.

Attempts were made to sustain primary digester temperatures between 94 and 98° F. This is the optimum temperature range for maintaining peak activity of the mesophilic anaerobes (5). An average temperature of 91° F. was actually achieved. Occasional clogging of the recirculating pumps was apparently responsible for this lower temperature. There was no heating or mixing in the secondary or tertiary digesters.

Bottom sludge concentrations in the secondary and tertiary digesters were low, due to frequent sludge transfers to the primary digester.

Table I shows digester results and compares them with the findings of others. The volatile solids were reduced 60 per cent and gas production

TABLE I.—Digester Results and Comparative Data

	Digester		Pilot-Plant Digester*	Conventional Practice
	Primary	Secondary		
Volatile solids (lb./cu. ft./day)†	0.083	0.043	0.262	0.021 to 0.0315‡
Volatile matter reduction (%)	52.0	18.0	42.0	57 to 67 §
Gas production:				
Cu. ft./lb. volatile matter added	5.6	3.8	8.31	12.9 ||
Cu. ft./lb. volatile matter destroyed	10.8	21.0	——	——
Methane (%)	60	63	——	67 ¶
Detention time (days)	16.0	16.0	10.1	41.7 to 104.1 ‡
Volatile acids (p.p.m.)	570	786	317	100 to 500 §
pH	6.8	6.9	7.05	6.8 to 7.2 §
Alkalinity (p.p.m.)	2,700	2,796	——	2,000 to 3,500
Temperature (°F.)	91	90	94.8	85 to 95 §

* Reference (1).
† Based on digester capacity.
‡ Reference (16).
§ Reference (17).
|| Reference (17). Corrected for volatile solids.
¶ Reference (17). Average of 33 plants.

averaged 7.5 cu. ft. per pound of volatile matter added.

Greater stabilization of solids can be obtained by the use of the secondary digester. The authors believe that intensifying the agitation in the digester would not increase the stabilization unless a greater solids concentration was available. This is in accord with the findings in the aerobic system.

Optimum separation of supernatant solids required the use of a tertiary digester. As a result, the supernatant suspended solids content averaged 1,100 p.p.m. Suspended solids higher than this average usually indicated a high sludge blanket in the tertiary digester.

Laboratory results show that the maximum supernatant separation occurs in less than 24 hr. of quiescence. The addition and withdrawal of sludge material is a daily batch operation instead of continuous as in the primary digester.

In compliance with several suggestions, the floating covers of the digesters were lowered to reduce the digester volumes. Table II shows the average results of operating the digesters under these new conditions. The volatile solids were reduced 57.3 per cent and gas production averaged 6.44 cu. ft. per pound of volatile matter added. These results are comparable to those previously obtained (Table I). However, the suspended solids content of the supernatant from

TABLE II.—Results Following Reduction in Digester Volumes

Item	Digester	
	Primary	Secondary
Volatile solids (lb./cu. ft./day)*	0.1087	0.0719
Volatile matter reduction (%)	57.3	——
Gas production (cu. ft./lb. volatile matter added)	6.44	0.08
Detention time (days)	15.7	15.1
Volatile acids (p.p.m.)	768	1,000
pH	6.71	6.95
Alkalinity (p.p.m.)	2,697	2,820
Temperature (°F.)	91	87

* Based on digester capacity.

the tertiary digester was reduced to 850 p.p.m.

Conclusions

1. Maximum plant construction economy can be obtained by utilizing a system which employs a denser sludge and a high degree of agitation.

2. The increased-rate sludge digestion process is successful but to date it has not been possible to investigate maximum loading due to an insufficient supply of raw sludge. However, the present facilities of the Bergen County treatment plant could accept at least 125 per cent of the current solids load with a high degree of efficiency. In addition, it is believed that further alterations in the digestion process may conserve still more capacity.

3. Although the sludge from the primary digester is of a satisfactory quality to be discharged for final disposal, it is beneficial to utilize a secondary digester as a polishing digester to remove larger quantities of volatile material and to obtain better separation of the liquid and solids.

4. Digester scum layers did not increase in thickness during the study period.

5. Supernatant from the secondary digester could not be relied on to maintain a sufficiently low solids content, thereby necessitating a tertiary digester to protect the primary sedimentation and secondary treatment processes.

Acknowledgment

The experimental work was carried out in consultation with Bogert and Childs, Consulting Engineers. The authors are indebted to the staff of the Bergen County sewage treatment plant for establishing the successful operation of the digestion process.

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A SIMPLIFIED GREASE DETERMINATION FOR SLUDGES AND SCUM

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The importance of foreseeing excessive grease-scum build-ups in digesters and digester piping is normally essential in averting serious digester problems. However, the number of grease analyses on liquid sludges is limited in the average sewage treatment plant laboratory to a bare minimum due to the time and equipment involved. Therefore, a method of good reproducibility, as well as accuracy, which could be run as a daily routine analysis without overtaxing laboratory hours or equipment and would fit in the average laboratory schedule to afford close scrutiny of the everpresent grease-scum problems is greatly desired.

A method has been employed in the laboratory of the Nut Island Sewage Treatment Plant laboratory since 1954 with consistent and indicative results. It was devised as a modification of the direct mechanical extraction method as stated by Theroux, Eldridge and Mallman (1). The procedure is such that it may be employed in other similar laboratories with equal success and practicality.

Procedure for Simplified Method

The simplified method involves five basic steps.

Acidification

Acidify approximately 100 ml. of the sludge sample with 0.5 ml. of concentrated hydrochloric acid.

Weighing of Sample

Prepare an 11-cm. Whatman 43 filter paper (fat free) as a lining for a 150-mm. glass evaporating dish; onto this filter paper lining weigh 10 g. of the acidified sample (to the nearest 0.1 g.).

Drying

Place evaporating dish with lining and sample into a 103° C. drying oven for 30 to 45 min., or until sample is dry.

Extraction

Wrap sample within the filter paper lining and place in Soxhlet thimble.

Rinse bottom of glass evaporating dish with petroleum ether and pour into tared Soxhlet flask.

Extract in Soxhlet apparatus, using 35° to 60° petroleum ether, for 4 hr. at 20 cycles per hour.

Final Weighing

Distill off or evaporate ether, then dry flask using vacuum to remove end traces of ether. Cool and weigh.

$$\text{Per cent grease (dry basis)} = \frac{\text{(gain in weight of flask) (100)}}{\text{(total solid of sample) (sample weight)}}$$

Except for the Soxhlet apparatus which would normally be set up and used for sewage grease determinations, only a minimum amount of equipment is required. A maximum of 45 to 60 min. is required to acidify, weigh, and dry the sample, and the extraction is carried on without personnel attention or supervision. The total solids determination would normally be made and the result used in the calculation for grease. It is suggested that the sample be homogenized before acidification and weighing, to facilitate weighing of the sample. In the test analyses discussed herein, homogenization was not practiced and the re-

covery and reproducibility obtained were easily within tolerable limits.

Verification of Method Efficiency

In the following experimentations, a sample of commercial bar soap was homogenized and analyzed for available petroleum-ether grease using the Sanderson-Smith Grease Recovery Method (2)(3). This analyzed soap was used to introduce known amounts of grease into the prepared sludge samples for the recovery tests. Samples of both raw and digested sludges were used as controls and were run in duplicate. Initially it was thought to make a known mixture of soap shavings and fat-free banding sand and to use this mixture solely to test the efficiency of grease recovery with the simplified grease method. However, difficulty in keeping the sand and soap shavings in homogeneous suspension disqualified this approach and suggested the use of sludge as a binder for the soap shavings. This procedure proved satisfactory and once mixed, the sludge and soap remained in intimate suspension.

The adopted procedure in testing for the grease recovery of the simplified method was as follows:

1. A mixture of 50 g. of sludge and 1 g. of soap shavings was prepared, the latter was weighed analytically. As previously reported, the grease content of the soap was determined by the Sanderson-Smith Method and showed a petroleum-ether grease content of 84.97 per cent. Consequently, by adding 1 g. of soap to the sludge, the quantity of grease in the sludge binding mixture was increased by 849.7 mg. It is to be noted that the percentage solid content of the sample was not considered when testing for grease recovery alone.

2. The mixture was acidified with concentrated hydrochloric acid to a pH of 1.0 and then 10 g. were weighed onto a tared Pyrex evaporating dish lined with a 11.0 cm. Whatman 43 filter paper. The 10 g. of sludge mixture contained 0.2 g. of soap which contributed an increase in grease content of 169.9 mg.

3. The sample was dried in a 103° C. oven, rolled within the filter paper lining and placed in a thimble for extraction.

4. The evaporating dish was rinsed with petroleum ether into a tared Soxhlet flask and then the grease was extracted from the sample for 4 hr. in a standard Soxhlet apparatus at a rate of 20 cycles per hour.

5. The Soxhlet flask was cooled and weighed, and the increase in weight attributed to the extracted grease.

This procedure was run simultaneously on "adulterated sludge samples" (containing the artificially added soap grease) and on "unadulterated sludge samples" (as normally collected) which served as controls. It was theorized that to obtain 100 per cent recovery, the amount of grease in the "adulterated sludge sample" should be consistently heavier than the "unadulterated sludge sample" by a weight of 169.9 mg. (the added grease weight). Therefore, the daily fluctuation in the normal grease content of the sludge would be cancelled since it would appear equally in both samples and the precision and accuracy of the determination would be based upon recovery of the 169.9 mg. of soap grease. As a further test for the reproducibility of the determination, one series of tests was run using raw sludge as the binding medium and a second series was run using digested sludge as the binding medium. In both series all samples were run with control duplicates.

Results

The percentage recovery for the added soap grease are listed respectively for raw sludge and digested sludge as binders in Tables I and II.

Table I shows an accuracy range from 89.9 to 106.4 per cent with a mean of 98.2 per cent. Table II shows an accuracy range from 93.7 to 110.3 per cent with an accuracy mean of 100.9 per cent.

The precision of the determination was found to have a standard deviation of ± 9.1 mg. when using raw sludge as the binding medium control and a standard deviation of ± 8.6 mg. when using digested sludge as the binding medium control. Such deviations allow a 95 per cent confidence limit from the mean of ± 5.1 and ± 3.6, respectively. Table III shows that the comparative standard deviation of the two series was further calculated to be ± 9.0 mg., which in turn allows a 95 per cent confidence limit of ± 3.0.

Extended Results

As a point of interest, it was decided to run duplicate analyses using the Sludge Grease Determination Method as outlined in the 9th Edition of *Standard Methods* (4) along with this simplified method. The duplicate samples were analyzed as collected (without the addition of artificial soap grease). An average of 8 duplicate test runs showed a mean grease content of 15.2 per cent by "Standard Methods" and a mean grease content of 19.4 per cent by the method described herein, or an increase in recovery by this latter method of 21.6 per cent.

TABLE I.—Soap and Grease Recovery Using Raw Sludge as a Binder and Control

Control Sample (mg.)	Control + Soap Sample (mg.)	Recovered Soap (mg.)	Percentage*
104.0	284.8	180.8	106.4
83.0	259.5	176.5	103.9
92.7	268.5	175.8	103.5
64.1	235.3	171.2	100.8
67.4	237.2	169.8	99.9
55.7	225.4	169.7	99.9
77.1	246.4	169.3	99.6
84.1	245.9	161.8	95.2
90.7	251.0	160.3	94.4
80.4	240.3	159.9	94.1
83.6	236.9	153.3	90.2
69.8	222.5	152.7	89.9
Avg. 79.4	246.1	166.8	98.2

* Based on 169.9 mg. of added soap yielding 100.0 per cent.

TABLE II.—Soap and Grease Recovery Using Digested Sludge as a Binder and Control

Control Sample (mg.)	Control + Soap Sample (mg.)	Recovered Soap (mg.)	Percentage*
36.7	224.2	187.5	110.3
48.8	236.2	187.4	110.2
55.9	242.5	186.6	109.8
66.4	249.6	183.2	107.8
45.7	221.9	176.2	103.7
40.6	216.2	175.6	103.4
48.3	222.3	174.0	102.4
56.4	230.1	173.7	102.2
38.3	209.6	171.3	100.8
49.1	220.3	171.2	100.7
43.6	214.6	171.0	100.6
52.1	222.5	170.4	100.3
59.8	229.4	169.6	99.8
61.6	231.0	169.4	99.7
46.6	215.8	169.2	99.6
57.6	224.9	167.3	98.5
37.2	203.2	166.0	97.7
76.0	238.9	162.9	95.9
75.3	237.4	162.1	95.4
69.8	231.6	161.8	95.2
60.9	220.1	159.2	93.7
48.9	208.1	159.2	93.7
Avg. 54.3	225.4	171.6	100.9

* Based on 169.9 mg. of added soap yielding 100.0 per cent.

TABLE III.—Comparative Final Results

Factors	Series I, Raw Sludge Binder (mg.)	Series II, Digested Sludge Binder (mg.)	Series I and II (mg.)
Theor. recovery	166.8	171.6	169.2
Actual recovery	169.9	169.9	169.9
Range	28.1	28.3	34.8
Analyses, No.	12	22	34
Standard deviation	±9.1	±8.6	±9.0
95 per cent confidence limit	±5.1	±3.6	±3.0

Discussion

It is noted in the procedure that acidification is accomplished prior to weighing; this was required since direct acidification on the filter lining caused the destruction of the filter paper as a liner. The weight of the acid used, as well as the slight increase in solid content of the sample due to the added soap, apparently did not significantly affect the over-all sludge weight within the 0.1 g. tolerance of the trip balance. The results in Table III indicate that the series using digested sludge as the binder allows closer duplication. This is probably attributable to the fact that digested sludge, being of a homogeneous character, presents a better sampling medium than raw sludge. However, the tolerance allowed by the raw sludge series and by the over-all comparison does not discredit the determination by allowing excessive deviation.

As to the comparison between the "Standard Methods" determination and the determination outlined in this paper, reference is drawn to the work of Gilcreas *et al* (3), in which it was found that boiling of the sample has the potentiality of driving off some volatile fats and thereby leads to a smaller yield. Unfortunately, comparative studies with the new method as outlined in the 10th Edition of *Standard Methods* (2) were not made but are anticipated for the future.

Summary

The simplified sludge grease determination as described and tested was proposed due to the demand for normal sludge grease control analyses, and to a search for a laboratory method which would yield a precision and accuracy as dictated by the tolerances and facilities of daily routine analyses. An over-all recovery mean of 98.2 per cent encompassed within a recovery range from 89.9 to 106.4 per cent when testing raw sludge as a binder and control; and a recovery mean of 100.9 per cent encompassed within a recovery range from 93.7 to 110.3 per cent when testing digested sludge as a binder and control were obtained. These results along with an over-all comparative standard deviation of $\pm$ 9.0 mg. and a 95 per cent confidence limit from the mean of $\pm$ 3.0 mg. conclude a sufficiently precise and accurate determination for the daily routine analysis of sludge grease or scum content.

The usual demands of time, equipment and dexterity in preventing recovery losses have been greatly minimized without sacrificing the end result. This permits the handling of more sludge grease analyses in the sewage treatment plant laboratory for control and efficiency evaluations.

Acknowledgments

The work herein described was accomplished by the personnel of the Nut Island Sewage Treatment Plant laboratory and Joseph B. Hanlon, Superintendent. Assistance in conducting these tests was rendered by V. A. Palombo, and H. F. Dennin.

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Annual Report of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1955 *

By Hugh A. Schreiber, *Superintendent*

The average daily sewage flow remained practically at the 1954 rate of 159.4 m.g.d. Construction of the sludge drying and incineration facilities and the chlorination units was completed in February, 1955. Plans for high-rate activated sludge secondary treatment were progressing.

Supervision of the institutional sewage treatment plants of the District of Columbia in the adjacent states of Maryland and Virginia was continued.

Treatment

Grit removal averaged 9.5 cu. yd. per day or 1.6 cu. ft. per million gallons of sewage. Studies are being made to determine the feasibility of aerating the grit chambers to accomplish more effective removal of the fine grit.

Suspended solids and B.O.D. removal efficiencies decreased 5.3 and 2.3 per cent, respectively, from the previous year. The strength of the sewage varied inversely with the flow, being low in July and high in January. Population equivalents are calculated on the basis of a per capita 5-day B.O.D. of 0.18, although this may not be representative since considerable garbage is ground and discharged to the treatment plant. The additional load of ground garbage is reflected in a higher B.O.D. loading. A total of 8,265 tons of garbage was ground, an increase of 847.3 tons over the previous year.

Sludge Digestion and Filtration

The 11 digesters operated in parallel as single-stage digesters and produced an average of 683,000 cu. ft. of gas per day. This amounted to 8.1 cu. ft. per pound of volatile matter. The digesters were dosed in rotation.

During the year an unsuccessful attempt was made to clean the No. 4 digester. Ejectors and a positive displacement pump were used on the tank contents after dilution with water. However, the pump velocities were too low and the withdrawal lines became badly clogged with sand and debris. Plans are being considered to lower a high-capacity, non-clog submersible pump into the digester and attempt to pump the contents to a lagoon.

The two-stage elutriation wash, be-

* For last previous extract see This Journal, 27, 7, 860 (July, 1955).

gun in 1954, produced a consistently heavy sludge and the tank overflows were satisfactory. The wash water ratio of 2.8 to 1.0 resulted in the same alkalinity decrease as would have been obtained by a single wash employing 3.8 volumes of wash water. New sludge collecting mechanisms were installed.

In order to coordinate filter cake production with the operation of the new sludge drying equipment, the rotation rate of the vacuum filters was reduced in March 1955. This resulted in a drier, thicker filter cake with a reduction in the use of ferric chloride. The average moisture content of the filter cake was reduced to 68.6 per cent from the previous average of 72.0 per cent. The use of ferric chloride was reduced from 5.37 to 4.11 per cent. Efforts are being made to reduce the ferric chloride dose to 3.5 per cent with careful operation.

The filter cloths were replaced on four of the filters after an average service of 914 filter hours. Replacement was made with cloths which were 10 per cent nylon and 90 per cent wool. One of the replaced cloths was 100 per cent nylon.

During the year 21,079 tons of wet filter cake were produced with an average solids content of 29.3 per cent.

TABLE I.—Summary of Operating Data for the Fiscal Year 1955, District of Columbia Sewage Treatment Plant

Item	Average
Sewage flow (m.g.d.)	159.2
Equiv. pop.	1,092,000
Grit removed (cu. ft./m.g.)	1.6
Solids (%)	70.3
Volatile (%)	17.0
Suspended solids:	
Raw sewage (p.p.m.)	171
Effluent (p.p.m.)	85
Reduction (%)	50.3
B.O.D., 5-day:	
Raw sewage (p.p.m.)	150
Effluent (p.p.m.)	107
Reduction (%)	28.7
Raw sludge:	
Removed (lb., dry/day)	114,400
Solids (%)	7.4
Vol. solids (%)	71.5
Grease (%)	24.9
Scum:	
Removed (g.p.d.)	16,554
Solids (%)	11.2
Volatile (%)	90.5
Sludge digestion:	
Vol. solids added daily (lb., dry)	84,300
Dig. sludge removed (g.p.d.)	72,000
pH, dig. sludge	7.2
Temp., dig. sludge (°F.)	88.7
Grease, dig. sludge solids (%)	9.6
Susp. solids, supernatant (p.p.m.)	17,500

Item	Average
Sludge gas:	
Total prod. (cu. ft./day)	683,000
Used (cu. ft./day)	444,633
Wasted (cu. ft./day)	238,367
Produced (cu. ft./cap./day)	0.6
B.t.u., gross (per cu. ft.)	647.5
B.t.u., net (per cu. ft.)	594.6
Methane (%)	59.8
Carbon dioxide (%)	33.8
Elutriated sludge:	
Solids (%)	7.9
Vol. solids (%)	47.9
Ratio, wash water to sludge vol.	2.8
Alkalinity, dig. sludge (p.p.m.)	3,460
Alkalinity, elut. sludge (p.p.m.)	716
Effective wash-water ratio	3.8
Elutriate:	
Susp. solids (p.p.m.)	1,830
Alkalinity (p.p.m.)	1,220
B.O.D., 5-day (p.p.m.)	615
Sludge dewatering:	
Dewatering time, total (days)	237
Filter hours, total	4,400.2
Cake produced, total (tons, wet)	21,079
Solids in cake (%)	29.3
Dry solids in cake, total (tons)	6,172.7
Yield of solids (lb./sq. ft./hr., dry)	5.6
$FeCl_3$ (%)	4.9
Susp. solids in filtrate (p.p.m.)	71

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The cost of drying this sludge amounted to $25,627. Filtration costs were $73,280.

Laboratory

Approximately 21,000 routine analyses were made throughout the year. These included daily composites of the raw and treated sewage, analyses of the elutriation process, filter efficiencies, and sludge drying. Routine sampling of the Potomac and Anacostia rivers was continued from 15 sampling stations.

Assistance was given to the District of Columbia institutional sewage treatment plants and adjacent Naval installations.

Operating Costs

Operating costs are distributed to actual sewage treatment functions. Power plant operation is charged 85 per cent to electrical energy and 15 per cent to plant heating. Operating charges are listed as follows:

Administration	$ 30,894
Laboratory	19,355
Sewage pumping	94,097
Grit removal	22,262
Grease separation	4,854
Grit disposal	2,058
Sedimentation	54,271
Sludge digestion	24,715
Sludge elutriation	6,793
Sludge dewatering	73,280
Sludge drying	25,627
Chlorination	470
Shops	4,436
Plant grounds	18,901
Inventory	12,010
Total	$ 394,023
Unit costs:	
Treatment ($/m.g.)	6.98
Pumping ($/m.g.)	1.62
Sludge cake disposal, wet ($/ton)	1.22

The increase in the cost of treatment from $5.96 per million gallons in 1954 to $6.98 per million gallons in 1955 results principally from the increase in personnel necessary to operate the sludge drying and incineration unit.

Operating data for the fiscal year 1955 are summarized in Table I.

Report of the Toledo, Ohio, Sewage Treatment Plant for the Years 1954 and 1955 *

By A. H. Niles, *Commissioner, Division of Sewage Disposal*

General

The recorded precipitation for 1954 and 1955 was near normal (31.84 in.) following a low of 22.95 in. in 1953. Accordingly, the flow increased to an average of 47.26 m.g.d. for the two-year period. The increased flow resulted in a suspended solids and B.O.D. reduction in the raw sewage. In 1953 the suspended solids averaged 214 p.p.m. and the B.O.D., 243 p.p.m. However, the total amount of suspended solids received has increased slightly over 1953. During 1954 and 1955 the suspended solids totaled 26,921,000 and 26,910,000 lb., respectively. Industrial wastes did not present any particular problems.

Equipment

When the raw sewage pumpage rate exceeds 90 m.g.d., the Detritor grit removal units are not effective due to increased velocity of flow. These inorganic solids are pumped to the digester along with the sludge, where they place an overload on the digester stirring mechanism. As a result, worm gears are unduly worn and frequently break. Repairs must be made within 2 to 3 hr. because a delay beyond this time will allow the heavy solids material to settle around the bottom scraper blade. It is impossible then to start the stirring mechanism and the 1,200,000 gal. of sludge in the digester must be removed. It is expected that the new preaeration, and grit and grease removal facilities constructed

* For last previous extract see This Journal, **27**, 6, 748 (June, 1955).

in 1955 will relieve this condition. Immediate benefit will not be experienced, since the accumulated solids must first be withdrawn in the normal process of operation.

Construction of the pretreatment facilities during 1955 interrupted normal plant operation from August 14 to October 18. During this period the plant was completely by-passed via the lift stations while necessary by-pass channel construction was completed at the treatment plant. It will be mid-1956 before the preaeration tanks can be utilized.

The gas engines received their annual overhauling during the plant shutdown in 1955 rather than as usual in October and November. During September and October there was only sufficient gas to supply heat for hot water for lavatories and shower baths; this was a result of by-passing the plant.

TABLE II.—Summary of Operation of the Toledo (Ohio) Sewage Treatment Plant for 1954 and 1955

Item	Average 1954	1955
Rainfall (in.)	32.19	28.69
Design flow (m.g.d.):		
Mean, dry weather	80.0	80.0
Max., dry weather	140.0	140.0
Max., storm	170	170
Raw sewage flow (m.g.d.):		
Minimum	26.53	31.59
Maximum	103.73	88.61
Average	47.20	47.33
Screenings (cu. yd./mo.)	247	221
Grit removed (cu. yd./mo.)	101	89*
Suspended solids (p.p.m.):		
Raw sewage	190	186
Plant effluent	93	97
Per cent removal	50.8	47.5
B.O.D. (p.p.m.):		
Raw sewage	199	190
Plant effluent	146	135
Per cent removal	26.8	28.2
Digester gas (mil. cu. ft.):		
Total produced	99.69	75.27
Utilized	82.80	65.42
Wasted	16.89	9.85
Volatile solids (%):		
Raw sludge	66.2	65.2
Digested sludge	41.4	40.2
Digested sludge (cu. yd.):		
To marsh	31,140	24,720
To drying beds	11,130	9,450
Dry sludge pulverized for fertilizer (tons)	823.48	704.34
Fertilizer sold (tons)	672.88	655.29
Total sales ($)	12,554.93	12,062.63
Chlorine:		
Pounds used	306,500	318,560
Days applied	76	79
Pumping station costs ($/m.g.):		
Bay View	6.48	6.62
East Side	22.50	26.84
Sewage works cost ($/m.g.)	10.44	11.19
Division cost ($/m.g.)	19.06	20.14
Gas engine economy ($):		
Pumping cost if power purchased	26,154.33	26,427.36
Actual pumping cost	12,938.73	16,063.12
Gas engine saving	13,215.60	10,364.24

* Ten months average.

Personnel

A staff of 66 employees maintain the division in first-class condition. In addition to the treatment plant, the sewage disposal division is responsible for the pumping stations. There are 22 employees with 15 years or more service with the division.

The average monthly pay roll in 1955 was $24,554.88. Vacation leave amounted to 6 per cent of this pay roll. Sick leave, excused leave, and service injuries accounted for 1.0, 0.5, and 0.6 per cent of the annual pay roll, respectively.

Tol-e-Gro

The drying and preparation of Tol-e-Gro has been at about the same rate for several years. In January 1954, the price was raised $3 per ton. As a result, the tonnage sold (672.88) was somewhat less than in 1953, but the total revenue remained approximately the same. Tonnage sold in 1955 (655.29) was again less than in previous years. The chemical fertilizers, which analyze higher than Tol-e-Gro, enjoy a better sale when the general economy of the people is at a high level.

The processing cost per ton increased from $5.68 in 1953 to $6.98 in 1955. This does not include general overhead and fixed charges, or the maintenance cost on the sludge beds and greenhouses.

Revenue

On August 15, 1954, sewage service charges were increased from 25 per cent of the water bill to 35 per cent, and resultant revenues were increased from approximately $778,000 in 1954 to about $950,000 in 1955. These revenues were just sufficient to finance the various activities dependent upon the sewage fund and provide a surplus to repay the preaeration and grit and grease removal improvements within three years.

The sewage service charge ordinance was amended again, effective January 1, 1956, to provide increased revenue. The estimated income that will be produced by the new rate is approximately $1,500,000 per year. This should be sufficient to pay the cost of operation of the division, the mainteance of the sanitary sewers, and to provide a sinking fund for revenue bonds which will be issued in 1956 to finance construction of secondary treatment facilities.

The new sewage service charges are based on the monthly water rates. Billings will be on a quarterly basis.

Flow (cu.ft. per month)	Rate ($ per 1,000 cu.ft.)	
	Toledo	Adjacent Area
0–10,000	$0.86	$1.21
Next 150,000	0.82	1.15
Over 160,000	0.66	0.92
Minimum quarterly charge	1.40	1.95

A summary of 1954 and 1955 operating data is given in Table II.

LOCATING SURFACE WATER CONNECTIONS TO SANITARY SEWERS

By V. V. Cottrell

Versailles, Ohio

Whether or not a municipal sewer system is overloaded, economies usually result when excess flow is eliminated. Storm-water inlets from downspouts or other drains and unauthorized connections for draining air conditioning water or other clean waste are a source of considerable flow. This is particularly true during rainy weather when treatment facilities are generally overtaxed.

In Versailles, Ohio, a village with a population of 2,000, the responsible officials developed a method of detect-

ing downspout and surface drain connections using standard insecticide fogging equipment.

Equipment

Equipment consists of a 75 c.f.m. air compressor operating at 100 p.s.i., an insecticide-type spray gun suitable for heavy duty service, 15 ft. of twin supply hose, and a deodorant base oil for creating fog. Disinfectants and insecticides can be added to the base oil for double-duty operation. A supply of various sized sewer plugs is also needed. One gallon or less of the oil will produce sufficient fog for the usual test of small lines, 8 in. to 15 in.

Procedure

Actual operations should be conducted during a period of reduced flow in the sewer and preferably on a clear, cool, windless day. The objective is to locate, through the emission of fog, the vents and other tell-tale openings on buildings connected to the sewer being checked. A sketch map of the street and buildings facilitates detection of the various vents.

The section of sewer to be checked is first blown clean of gases and odors with compressed air from the air compressor. A soil pipe test plug or similar fitting is placed in the inlet sewers to the upstream manhole to stop temporarily the flow of sewage. Another plug is placed in the upper end of the sewer to be checked, to prevent the escape of fog to the manhole.

The air compressor, fog nozzle and hose are located at the downstream end of the sewer to be checked. A test plug, with the long shaft cut off to enable easy introduction of the fog nozzle, is placed in the sewer. The fog is then introduced into the sewer. (The air line is connected to the compressor and the end of the liquid line is immersed in the base oil.) The fog nozzle is held loosely in the opening in the plug to prevent the buildup of excess pressure and the subsequent blowing of traps in the plumbing systems of the buildings.

Usually within 5 min. fog can be observed escaping from toilet vents, downspouts, cistern overflows, surface drains, and other connections that are not trapped. The crew quickly notes the fog discharges on the prepared sketch. The use of several checkers expedites the survey and insures that few if any connections will be overlooked.

After the fog has been introduced into the sewer it is sometimes desirable to introduce a larger volume of air to flush out the system and to identify any other connections. This additional air can be obtained from the air compressor.

This system has been put to effective use in Versailles where the sewer sizes range from 8 to 15 in. However, the method should work with larger pipe sizes, provided the fog and air quantities are increased.

Acknowledgments

Assistance of the following is appreciated: H. R. Rich, Entomologist, Knox Chemical Company, Chicago, Ill.; E. R. Baumann, Research Associate, Department of Civil Engineering, University of Illinois, and now Associate Professor, Department of Civil Engineering, Iowa State College; and Professor K. W. Cosens, Department of Civil Engineering, Ohio State University.

TIPS AND QUIPS

Professional Improvement

A training program to provide upgrade training for persons employed in the field of sanitation and to train persons for positions open in the sanitation, sewerage works, and industrial wastes fields has been added to the evening, adult education curriculum of a junior college in California. The two-year program draws upon lay ex-

perts in the field for instructional purposes.

Activated Sludge for the Home

Small, compact activated sludge units to handle the sewage from an individual home have been studied for several years. Within the last year several units have made their appearance on the market. The Yeomans Brothers Company exhibited an aeration unit at the 1955 Federation Meeting and suggested its use for one-house service. More recently a commercial unit has been reported which embodies some of the features studied at Purdue University by Professor Bloodgood.

This "sewerless" toilet system economizes on water use by using the aeration tank liquor for toilet flushing purposes. A water saving of 50 per cent is anticipated through this re-use of flushing water. All household wastes are directed to the unit, except garbage-grinder wastes. The effluent must be disposed of to a drainfield, seepage bed or other absorption system. Problems of the conventional septic tank drain field are lessened due to reduction in the volume of the waste and a better quality of effluent.

Continuous aeration is provided by a 75 w. air compressor. Operating results from Purdue indicate an effluent B.O.D. of 20 p.p.m., an aeration solids range of 1,000 to 6,000 p.p.m., and a dissolved oxygen content of 2.5 to 8.0 p.p.m.

Some units have been installed in subdivisions throughout the United States. Estimated cost for the unit and installation is approximately $600. The unit has not as yet received the official approval of state and Federal sanitary engineers.

Safety and Operational Procedures for Laboratories

General

1. Goggles should be worn when performing hazardous operations, such as handling corrosive materials or heating glassware to high temperatures.

2. Wear asbestos gloves when handling hot materials.

3. Whenever possible use hoods when handling volatile, flammable materials.

4. Don't leave or use flammable solvents around fire or heat. Keep number of containers of same in laboratory to a minimum.

5. Don't handle or repair "hot" electrical equipment around water.

Broken Glassware

1. Do not use cracked glassware.

2. Fire-polish sharp or chipped edges.

3. Don't pick up broken glass with bare hands. Use tongs for large pieces and wet cotton for small pieces.

4. Place all broken glass in trash cans. Never throw it in.

Handling Glassware

1. Never put excessive pressure on glassware with bare hands.

2. Never try to force rubber tubing or stoppers from glassware. Cut the rubber or material off.

3. Never dilute strong alkalis or sulfuric acid in Kimble or soft glassware.

Use of Equipment

1. Never try to force moving parts. A little patience and proper tools will usually remedy the situation.

2. If you don't know how to operate a certain piece of equipment, ask someone who does.

3. Use the proper tools in the proper places. For example: don't do any pounding on a balance table or use a saw on top of a laboratory bench.

4. Don't leave incubator, oven, furnace, or refrigerator doors open. Close as quickly as possible.

Housekeeping

1. Maintain cleaning schedule.

2. Don't postpone cleaning up a mess. Do it as soon as possible.

3. Liquids spilled on the floor should be mopped up immediately.

General Laboratory Techniques

Graduates with bad pouring lips should not be used for corrosive liquids. Concentrated sulfuric acid and sodium hydroxide are very viscous and great care should be taken when making volumetric transfers in pipettes to avoid dripping on counters and floors.

Cleveland, Ohio, Safety Record

Cleveland, Ohio maintains a Division of Employees' Accident Control which tabulates exposure, frequency and severity of accidents, and other safety factors on a city-wide basis. During the third quarter of 1955 the Division of Sewage Disposal had an exposure of 109,029 man-hours. Nine injuries (eight medical cases and one lost time) during this period, resulted in a total of 82 days of lost time.

Hyperion (Calif.) Plant Wins Safety Award

Employees of the Hyperion sewage treatment plant were presented with an award plaque on March 21 by the Greater Los Angeles Chapter of the National Safety Council for placing second in the utilities group in the 1955 Business and Industry Safety Contest.

For 1955, the Hyperion plant had a safety frequency rating of 3.69, which represented only two disabling injuries in 500,000 man-hours of work. Effective in achieving this award were the cooperation of the plant employees and the efforts of the safety coordinators and safety committee members.

Plastic Pipe for House Connections

A lightweight, plastic pipe designed for sewer and drain applications is apparently being well received for house connections to sewer laterals or septic tanks. Complete resistance to moisture and corrosion, and smooth interior walls makes the pipe readily adapted to drainage systems.

A 10-ft. section of 4-in. pipe weighs only 14.5 lb. Jointing of sections is quickly accomplished by coating the exterior of the pipe ends and interior of the coupling with a special cement. The resulting joint is permanently sealed against roots and infiltration. The pipe is available in diameters from 2 to 6 in. Carlon Products Corp., 10225 Meech Ave., Cleveland 5, Ohio.

CO Indicator

A pencil-size carbon monoxide detector shows at a glance whether or not the concentration of carbon monoxide in the air tested is dangerous for occasional, short-time, or long-time exposure. The instrument (Figure 1) uses a carbon monoxide sensitive chemical, sealed in disposable glass tubes, as the indicator. A special aspirator pumps a given volume of air through the tube. The appearance of a brownish-gray color in the tube indicates the presence of carbon monoxide. The number of pumpings to obtain a color change is indicative of the concentration of carbon monoxide.

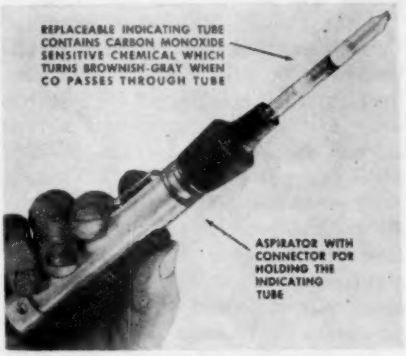

REPLACEABLE INDICATING TUBE CONTAINS CARBON MONOXIDE SENSITIVE CHEMICAL WHICH TURNS BROWNISH-GRAY WHEN CO PASSES THROUGH TUBE
ASPIRATOR WITH CONNECTOR FOR HOLDING THE INDICATING TUBE

FIGURE 1.—Carbon monoxide detector.

The instrument indicates only the presence or absence of carbon monoxide—it does not indicate the concentration as do some instruments

presently available. The instrument is simple to use since color changes need not be compared to a color chart in order to determine condition of the air. The price is $22.70 and additional information is available from Bacharach Industrial Instrument Co., 7301 Penn Ave., Pittsburgh 8, Pa.

Hand Cleaner

A waterless, liquid cream hand cleaner is available which reportedly removes difficult stains and grime from the skin, yet is as mild as a toilet soap. Handy dispensers are available. American Detergent Company, Inc., 370 7th Ave., New York 1, N. Y.

Vitamin B-12 Plant Under Construction

The presence of Vitamin B-12 in dried sewage sludge has been known for many years. Its value as a growth-stimulant additive for livestock and poultry feed and its increased use have drawn attention to sewage sludge as a ready, convenient source of raw supply. Research work over the past 10 to 15 years has perfected a method of Vitamin B-12 extraction from dried sludge that has economic potentials.

Although the Milwaukee Sewerage Commission did not consider it advisable to go into Vitamin B-12 production, it has encouraged the research work and even commissioned a consulting engineering firm to prepare plans and cost estimates for a Vitamin B-12 extraction plant at the site of the Milwaukee sewage treatment plant. However, nothing was done about plant construction when a lack of interest was evidenced by the principal producers of Vitamin B-12.

An exclusive agreement was then negotiated with the Alden Company, Engineers, for continued promotion of the process. Arrangements have recently been completed for the construction of the extraction plant. The Alden Company will own and operate the facility and the Commission will remain in the primary business of sewage treatment and fertilizer production.

The entire annual production of 200 lb. of pure Vitamin B-12 activity will be taken by Armour Laboratories, a division of Armour and Company, for veterinary use.

The extraction process uses dried sludge and will operate on a continuous, automatic basis, coordinated with the production of Milorganite, the trade-marked brand of dried, sterile sludge from the Milwaukee sewage treatment plant. There will be no alteration in the fertilizer value of Milorganite. Only sufficient dried sludge will be used to meet the market demand for Vitamin B-12.

Plastic Filter Media

The National Council for Stream Improvement, Inc., reports that two paper mills are experimenting with trickling filters constructed with a new, lightweight plastic in place of the stone media. The plastic is formed in large interlocking sheets which provide large surface areas and voids. The light weight of this material makes feasible the construction of filters 30 ft. in depth.

Pollution Potential

The boat business continues to boom as Americans take to the water. This summer there was a boat afloat for every 29 persons in the United States.

Two problems face those who are entrusted with the responsibility for protecting the waterways of the country. The program for the abatement of pollution in streams and lakes must be hastened to provide more clean water for boating enthusiasts, and these part-time sailors (families included) must be educated to the dangers of their own pollution potential.

Editorial

THE 1956 WATER POLLUTION CONTROL ACT

With the enactment of the Water Pollution Control Act of 1956, the Federal Government has reasserted both its interest and concern in the role of pollution of the nation's water resources. With the approval of President Eisenhower on July 9, Public Law 660, 84th Congress, became the pattern of Federal activity in the field for the next few years.

The new law is largely an extension of the 1948 Act but it also includes some very important changes. Those who have followed the development of the new legislation are well aware of the fact that this legislation is the result of many compromises. In this respect it is similar to other legislation produced by a democratic assembly.

The new law will be administered by the U. S. Public Health Service, and this agency will be faced with many new duties. For example, USPHS will survey pollution discharges by Federal installations such as military bases, hospitals, prisons, and arsenals. These have often posed vexing problems for State Water Pollution Control Agencies.

While funds for research were reduced from previous years, this most important aspect of water pollution control will be continued at a rate and in a manner fully commensurate with the funds provided. More basic data on wastes and their response to treatment are certain to result to the benefit of all in the field.

Enforcement by the Federal Government in its jurisdiction will be strengthened, while grants to states will help maintain and extend the effectiveness of their pollution control measures. Under this same provision, interstate agencies are eligible for financial assistance. Where enforcement measures are required it now appears they will be at hand.

By far the most controversial provision of the legislation was the question of Federal construction grants-in-aid. The Federation, along with many other professional organizations, did not support this section at hearings before Congressional Committees. The complex formula of distributing the $50 million appropriation will require the greatest wisdom on the part of the Public Health Service. While it would seem to penalize those communities who have embarked on sewage treatment extensions in recent years, we must admit that if more had been accomplished previously, the question of such financial help would not have arisen. While it will be interesting to watch it work, we must all realize that it is up to those affiliated with the Federation to make it work for the maximum benefit of the public by improvement of our water resources.

R. E. F.

Reviews and Abstracts*

Improvements to New Bedford's Sewerage Facilities, Including Intercepting Sewers and Pumping Stations. By F. L. Heaney. *Jour. Boston Soc. Civil Eng.*, **42**, 4, 323 (Oct., 1955).

New Bedford is a city with a population of about 110,000, located on Buzzard's Bay, Mass. Combined sewers were built prior to 1900 which discharged into tidal waters and created offensive conditions. An intercepting sewer system with 9 pumping stations was started in 1912, with an outfall 3,000 ft. extending into the Bay to a depth of 30 ft. In 1920, only five stations had been constructed and work was halted. In 1947 the work was resumed.

The paper describes the determination of capacities of main interceptors and outfalls; the planning of new interceptors and pumping stations; overflow and regulating devices; screening and grit removal equipment; the effect of hurricanes (in 1938, 1944, and 1954); and measures to protect older pumping stations. New pumping stations are to be built.

Langdon Pearse

Extensions to the Wood End Sewage Disposal Works, Burnley. By I. B. Donald. *Jour. Inst. Munic. Eng.*, **82**, 357 (1956).

This paper describes the scheme for extending the County Borough of Burnley's sewage works at Wood End, and mentions some of the more interesting problems arising from the design and construction. Burnley County Borough is divided into two drainage areas, one draining to a sewage works near Altham, and the other draining to the Duckpits and Wood End sewage works. The latter was constructed about 1873 and has since been enlarged and improved several times. The present scheme was designed with a view to utilizing as much of the existing equipment as possible. Two primary settling tanks and five final settling tanks were proposed, and in addition, two distribution tanks, a sludge pump house and pumping plant for the return of activated sludge have been included. Information on which the design is based is tabulated and the proposed plan is shown diagrammatically.

D. E. Pascoe

Sewage Disposal Works, Spondon. By M. L. Francis. *Jour. Inst. Munic. Eng.*, **82**, 393 (1956).

History of sewage disposal in Derby, recounted from pre-1903, when sewers discharged directly into watercourses, through the providing of intercepting sewers and original Spondon Sewage Works, to the various modifications at the sewage works necessitated originally by flooding and later by increased sewage flow.

The new works already completed and designed to handle 15 m.g.d. (dry weather) include a microstrainer installation, stormwater tanks, a sewage pumping station, sedimentation tank modifications, biological filters and humus tanks.

M. B. Pescod

Automation in Some Aspects of Public Health Engineering. By L. E. Meeks. *Jour. Inst. Pub. Health Eng.*, **55**, Part II, 55 (April, 1955).

Discussion of British practices in applying automatic recording devices to public works, particularly sewage treatment facilities.

Langdon Pearse

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N. W., Washington 16, D. C.

Book Reviews

Proceedings of the Tenth Industrial Waste Conference. Eng. Bull., 40, No. 1 (Extension Series No. 87). Purdue Univ., Lafayette, Ind. 581 pp. Price, $2.50 (Mar., 1956).

The papers included in the "Proceedings" are those presented at the Tenth Conference, held May 9–11, 1955, as follows:

"Experience and Questions Concerning Aeration Methods as Applied to Dairy Wastes," by H. A. Trebler.

"Chemical Treatment of Paint and Pigment Wastes," by W. Wesley Eckenfelder, Jr., and Donald J. O'Connor.

"Pilot Plant Studies on Phenolic Wastes at Tinker Air Force Base, Oklahoma City, Oklahoma," by George W. Reid and Robert J. Janson.

"Vacuum Carbonate Process for Recovery of Hydrogen Sulfide and Cyanide Compounds," by H. A. Gollmar and W. W. Hodge.

"Disposal of Fine Chemical Wastes," by S. J. Paradiso.

"Plating Waste Solutions—Recovery or Disposal," by R. J. Keating and J. H. Duff.

"Dialysis of Caustic Textile Wastes," by N. L. Nemerow and W. R. Steele.

"Construction and Performance of Trickle Filters," by F. Majewski, J. Steen, and T. Iezzi.

"Biological Oxidation of Petroleum Phenolic Waste Waters," by W. K. Ross and A. A. Sheppard.

"Some Problems Encountered in Spray Irrigation of Canning Plant Waste," by R. A. Canham.

"Biochemical Oxidation of Dairy Wastes. VII. Purification, Oxidation, Synthesis and Storage," by Nandor Porges, Lenore Jasewicz and Sam R. Hoover.

"Treatment of Pulp and Paper Mill Effluents in the Kalamazoo River Valley," by Anthony J. Palladino.

"Statistical Design in Research," by Paul Irick.

"Molded Polystyrene Media for Trickling Filters," by Edward H. Bryan.

"Aerobic Oxidation of Corn Wet Milling Wastes," by Marion B. Foley, Roger J. Mauterer and G. James Dustin.

"Cyanide Destruction on Trickling Filters," by C. Fred Gurnham.

"Obtaining Design Data for Industrial Waste Treatment Plants," by W. T. Laffey.

"An Activated Sludge Plant for Pulp and Paper Wastes," by Theodore L. Moore.

"Dissolved Air Flotation for White Water Recovery," by Ralph I. Berman and Joseph Osterman.

"The Biochemical Oxidation of Synthetic Detergents," by R. H. Bogan and C. N. Sawyer.

"Some Experiences in the Pretreatment of Industrial Wastes Going to the Municipal Sewer System of Philadelphia," by J. S. Reich.

"Establishing Industrial Waste Ordinances," by Dean M. Taylor.

"A Volatile-Extractable Acid Method for Control of Anaerobic Digestion Processes," by J. F. Thomas, C. R. Wherry, and E. A. Pearson.

"Technology of Treating Plating Wastes," by N. S. Chamberlin and H. B. Snyder, Jr.

"Studies of High-Rate Composting of Garbage and Refuse," by John S. Wiley.

"Reduction and Control of Wastes in a New Refinery," by J. T. Zeien.

"The Location of Wet Process Industries," by Truman H. Safford.

"Treatment and Utilization of Winery Wastes," by E. A. Pearson, D. F. Feuerstein and B. Onodera.

"The Effects of Increased Temperatures Upon Aquatic Organisms," by John Cairns, Jr.

"Index Organisms Used in Louisiana Stream Pollution Surveys," by Frank J. Coogan, Robert A. Lafleur and Kenneth E. Biglane.

"Radioactivity in Water Supply Sources, Measurement and Removal," by E. J. Kilcawley and H. M. Clark.

"Vibrating Screens in Industrial Waste Water Treatment," by W. P. Stilz.

"Theory and Design of Mixers for Aeration of Waste," by J. Y. Oldshue.

"Process for Production and Handling of Lime Slurry for Use in Chemical Applications," by L. John Minnick and Clifton A. Danforth.

"Treatment of Fine Chemical Wastes by High-Rate Activated Sludge," by F. E. Dryden, P. A. Barrett, and J. C. Kissinger.

"Recent Developments in Waste Water Treatment by the Beet Sugar Industry," by L. T. Jensen.

"Fluoride Pollution of Ground Water by Industrial Wastes," by Sherwood Davies and Wallace W. Sanderson.

"The Treatment of Gray Iron Foundry Waste Water," by C. W. Hathaway, R. E. Harvie, and D. J. Flynn.

"The Potential Toxicity of Chemicals in Water for Man and Domestic Animals," by Jules S. Cass.

"Waste Treatment Plant Wolverine Shoe and Tanning Corporation, Rockford, Michigan," by George Hubbell.

"Ponding and Soil Filtration for Disposal of Spent Sulphite Liquor in Wisconsin," by T. F. Wisniewski, A. J. Wiley, and B. F. Lueck.

"Lagooning and Spray Disposal of Neutral Sulphite Semi-Chemical Pulp Mill Liquors," by Don Voights.

"Disposal of Liquid and Solid Wastes by Means of Spray Irrigation in the Canning and Dairy Industries," by L. C. Lane.

"Spray Irrigation of Dairy Wastes," by Frank J. McKee.

"Some Principles of Agricultural Irrigation," by Donald R. Sisson.

"Closed System Use of Industrial Water," by C. J. Lewis.

"Oil Removal Facilities for Steel Mill Wastes," by Michael F. Madarasz.

"Plant Scale Studies on the Biological Oxidation of Cannery Wastes," by W. Wesley Eckenfelder, Jr., and Edward R. Grich.

A cumulative index of the first 10 "Proceedings" is included.

D. P. SCHIESSWOHL

Engineering in History. By RICHARD S. KIRBY, SIDNEY WITHINGTON, ARTHUR B. DARLING, AND FREDERICK G. KILGOUR. McGraw-Hill Book Co., Inc., New York, N. Y. 530 pp. Price $8.50 (1956).

This distinctive volume covers the development of engineering from about 6000 B.C. to the present, in a general introductory manner which emphasizes those achievements which have appeared to have the most significant impact on civilization. The effects of civil, electrical, and some aspects of metallurgical and mechanical engineering, on human health and material welfare are considered.

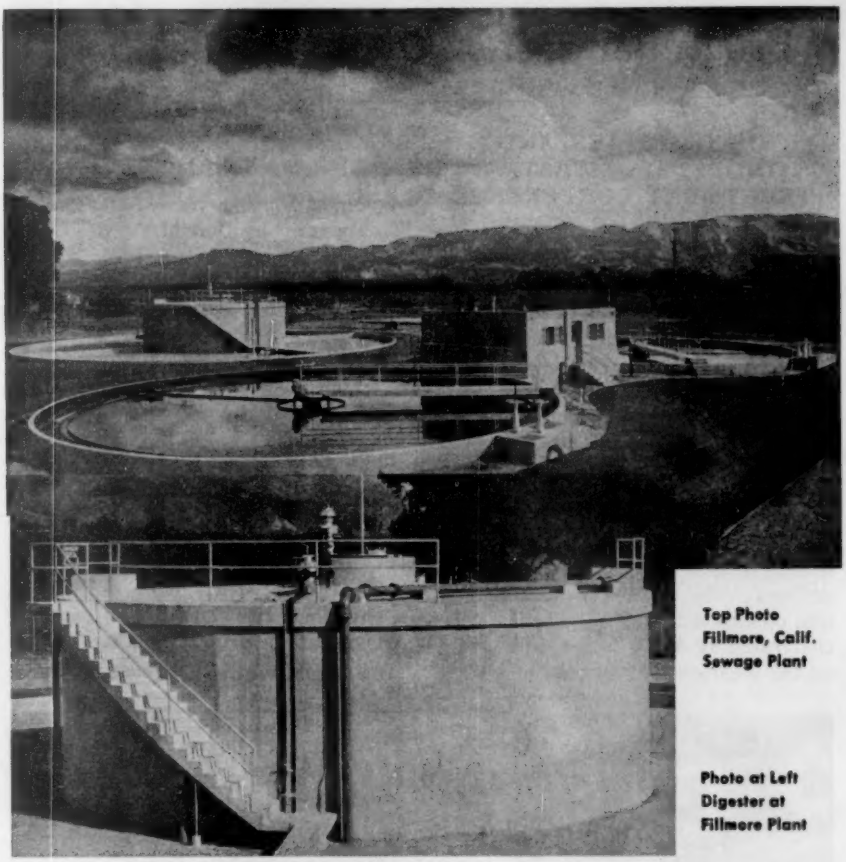
D. P. SCHIESSWOHL

The Municipal Year Book, 1956. By CLARENCE E. RIDLEY AND ORIN F. NOLTING, Editors. International City Managers Assn., 1313 E. 60th St., Chicago 37, Ill. 582 pp. Price, $10.00 (1956).

The 1956 (23rd) edition of this authoritative resume of activities and statistical data of American cities contains new sections on the urban problems which transcend the corporate limits of cities, metropolitan special districts, municipal insurance data for fire, general public liability and motor vehicle liability, home rule, and housing codes. Data on municipal garages and city-owned transit systems are included. The section on fringe-area problems reviews the tremendous growth in 1955 in the number of studies, reports and proposals for metropolitan areas. Annexations occurring in more than 500 cities during the year are analyzed.

The regular sections have been brought up-to-date and significant municipal developments during the previous year are reviewed. Summary articles precede each major table in the book.

D. P. SCHIESSWOHL



Top Photo
Fillmore, Calif.
Sewage Plant

Photo at Left
Digester at
Fillmore Plant

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Proceedings of Member Associations

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

The 30th Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Carter Hotel, Cleveland, Ohio, on June 13–15, 1956. Registered attendance was at a high with a total of 294, including 40 ladies.

The Manufacturers' Forum on June 13 featured discussions on vacuum filtration by representatives of Dorr-Oliver Inc., Eimco, and Komline-Sanderson Engineering Corp.

Concurrent sessions were held by the sewage treatment and industrial wastes sections. The Sewage Treatment Section opened with an Operators' Forum moderated by A. D. Caster, Cincinnati, on the technical supervision of sewage treatment facilities. Other papers presented included the following:

"Metal Plating Wastes and Sewage Treatment," by Donald Tarvin, Chemist, F. G. Browne & Associates, Marion.

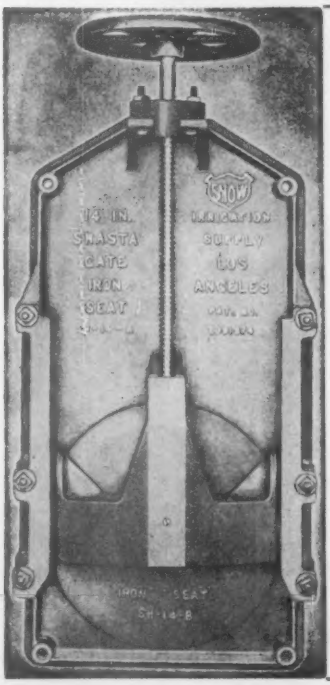
"Some Aspects of the B.O.D. Test," by Cleamon Lay, Chemist, Sewage and Industrial Waste Section, Ohio Department of Health, Columbus.

"Volatile Acids, An Index to Digestion," by James Frook, Chemist and Bacteriologist, Sewage Treatment Plant, Toledo.

"Training of Sewage Treatment Plant Employees," by A. D. Caster, Principal Engineer, Sewage Disposal, Cincinnati.

The Industrial Wastes Section opened with a forum on the disposal of solids by lagooning, incineration, sand filtra-

(*Continued on page 322a*)



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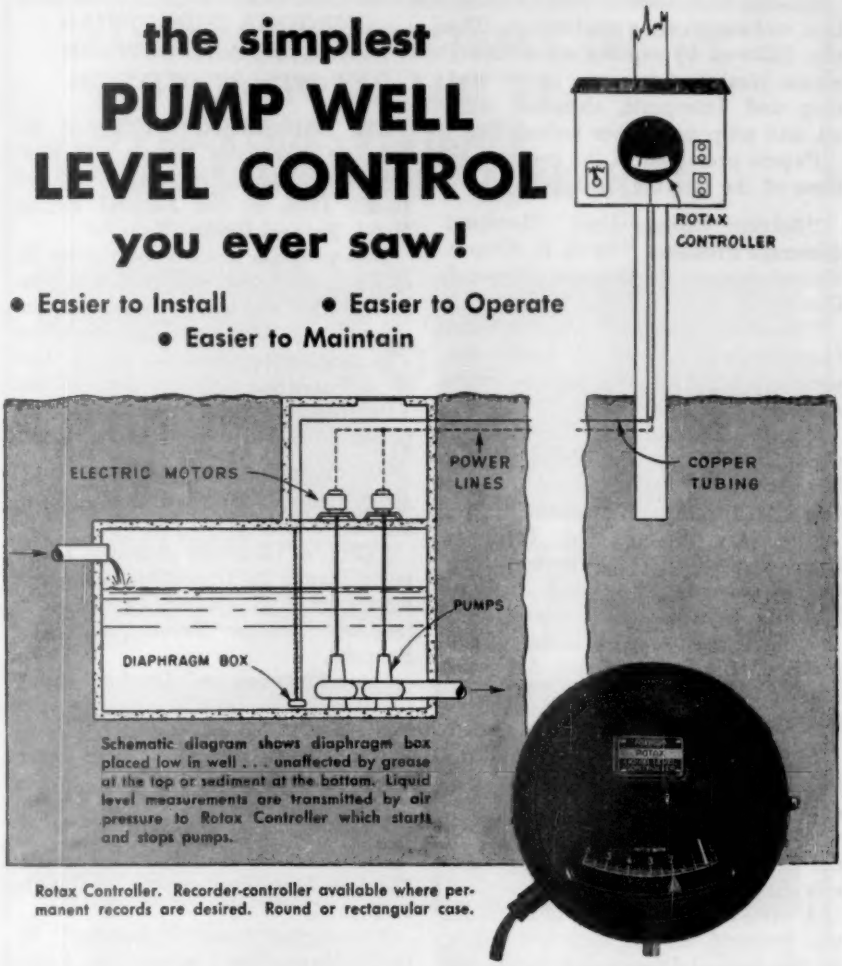

Schematic diagram shows diaphragm box placed low in well . . . unaffected by grease at the top or sediment at the bottom. Liquid level measurements are transmitted by air pressure to Rotax Controller which starts and stops pumps.

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PUMP WELL LEVEL CONTROL

tion, and evaporation combustion. This was followed by reports on industrial wastes treatment progress in the coal, soap and detergents, chemical, steel, oil, and pulp and paper industries.

Papers presented at the general sessions of the meeting included:

"Solving Metropolitan Cleveland Sewerage Problems," by G. E. Flower, Commissioner of Sewage Disposal, Cleveland.

"Southerly Sewage Treatment Plant Improvements," by W. E. Gerdel, Superintendent, Southerly Sewage Treatment Plant, Cleveland.

"Waste Treatment at Central Furnaces," by Wm. H. Weise, Works Metallurgist, American Steel & Wire Co., U. S. Steel Co., Cleveland.

"Sanitary Sewer and Drainage Planning," by P. M. Rowley, Consulting Engineer, Cleveland Regional Planning Commission, Cleveland.

"Characteristics of a Stream Composed of Oil Refinery and Activated Sludge Effluents," by F. L. Ludzack, Chemist, USPHS, Cincinnati.

Inspection trips were made to the flue dust recovery and sintering plant of the American Steel & Wire Co., waste oil separator at No. 1 Refinery of the Standard Oil Co., and the Southerly Sewage Treatment Plant.

A varied program of social activities was featured for the men and ladies. At the Annual Dinner and Dance, the Dean Stewart Award was presented in absentia to Herbert W. Hansen, Ravenna, and the J. W. Ellms Award was made to W. D. Sheets, Columbus.

Officers elected for 1956–57 were:

Chairman: Franklin Ruck, Troy.
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VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 10th Annual Meeting of the Virginia Industrial Wastes and Sewage Works Association was held April 19–20, 1956, at the Natural Bridge Hotel, Natural Bridge, Va.

Two program items of particular interest to operating personnel were featured. One was a panel discussion on operating problems and the other was a discussion by Professor J. D. Eye of the progress and problems of the VPI short schools. Technical papers presented included:

"Public Relations for Sewage Treatment Plants," by Ralph E. Fuhrman, Executive Secretary, FSIWA.

"City of Roanoke Sewage Treatment Plant; Its Operation and Problems," by F. C. Funnel, Jr., Superintendent, Sewage Treatment Plant, Roanoke.

"Air Flotation and Its Application to Sewage and Industrial Wastes Treatment," by Dr. J. D. Frame, F. S. Gibbs, Inc., Newton Lower Falls, Mass.

"Design of Septic Tanks and Small Sewage Treatment Plants," by E. C. Meredith, Director of Engineering, Virginia State Department of Health, Richmond.

"Measuring Flows in Sewers," by G. E. Clark, The Foxboro Co., Baltimore, Md.

At the business meeting the following officers were elected for 1956–57:
President: James J. Corbalis, Jr., Alexandria.
Vice-President: J. P. Kavanaugh, Roanoke.
FSIWA Director: Frank H. Miller, Norfolk.
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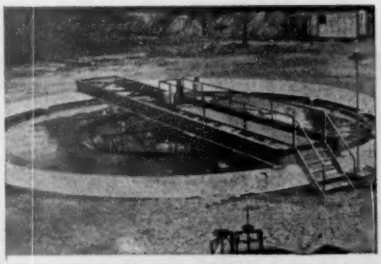

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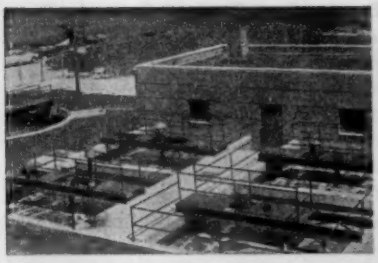

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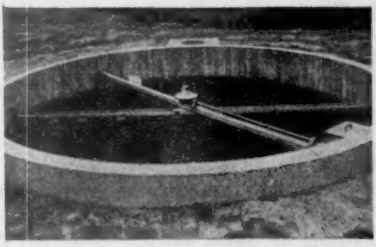

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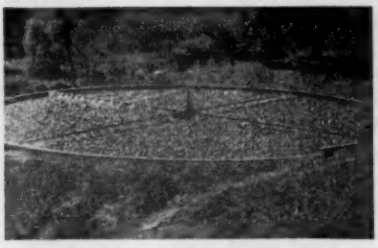

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Sequencing Timing Control—Data Sheet No. 11.12-1 describes an impulse counter method and a continuous timer method for obtaining sequence timing control.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Cyanide and Chromic Acid Control—Application Bulletin 90-242-10 describes chlorination and sulfonation methods for the treatment of cyanide and chromium wastes from the metal industries.—Fischer & Porter Co., Hatboro 35, Pa.

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Back-Flow Indicator—A visual flow indicator incorporating a self-aligning soft seat flapper is described in Catalog 10-A-83.—Fischer & Porter Co., 544 Jacksonville Rd., Hatboro, Pa.

Portable Emergency Lights—Two battery-operated portable emergency lights are described in a news release.—Carpenter Manufacturing Co., Boston 45, Somerville, Mass.

Telemeters—Illustrated Bulletin 230-H4A describes the operation and applications of Chronoflo telemetering equipment for recording and controlling the operation of pumps, feeders, valves and other units.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

Diaphragm Valve—A diaphram valve, which acts like a laboratory stopcock, provides "straight-through" flow for viscous materials, fibrous slurries, sludges and solids in suspension. Only the diaphragm is normally subject to wear, and replacement is easy.—Grinnell Co., Inc., 260 West Exchange St., Providence 1, R. I.

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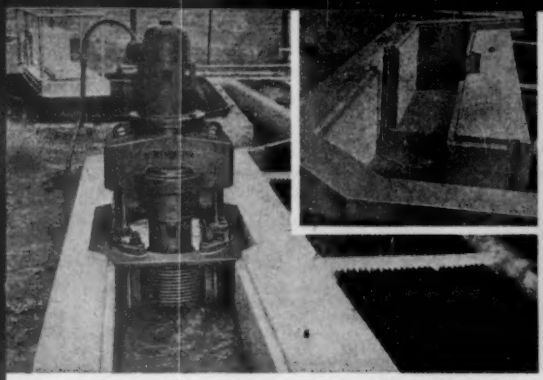
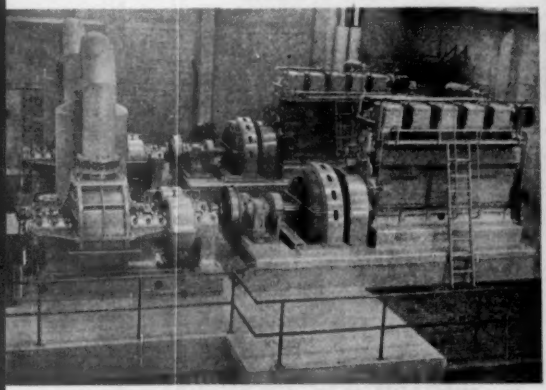


COMMINUTORS. Since raw sewage flows straight through in the Worthington design, the comminutor can be installed in a simple rectangular channel (inset) without expensive masonry work. This one is located at Klamath Falls, Ore.

MIXFLO PUMPS. Available in sizes from 2 MGD to over 300 MGD, Mixflo pumps have non-clogging sewage-type impellers for passing large solids. This one handles raw sewage in the new Salem, Ore., Treatment Plant.



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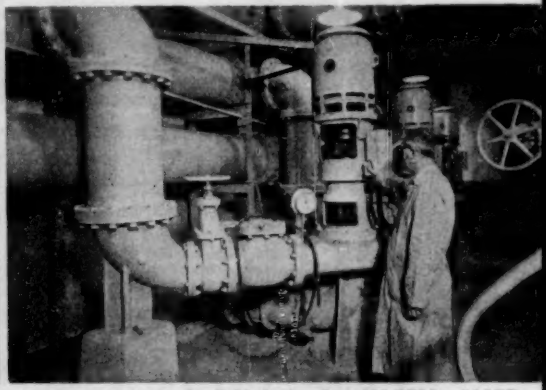

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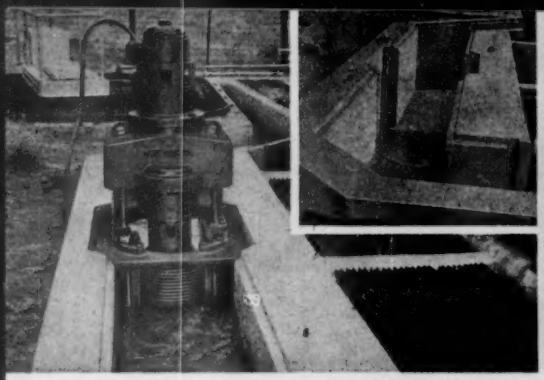

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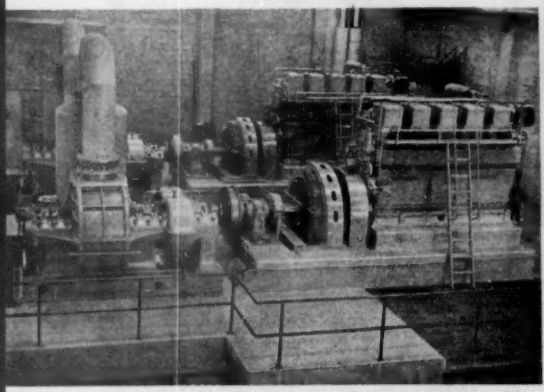

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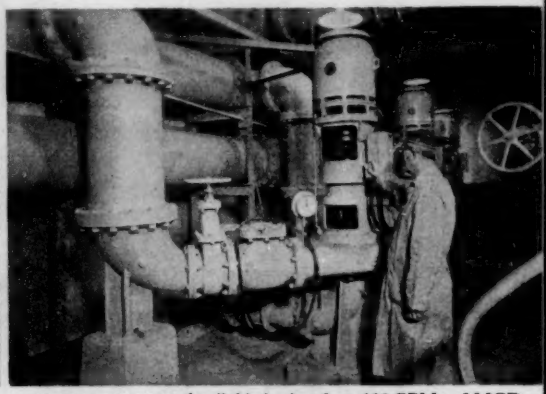

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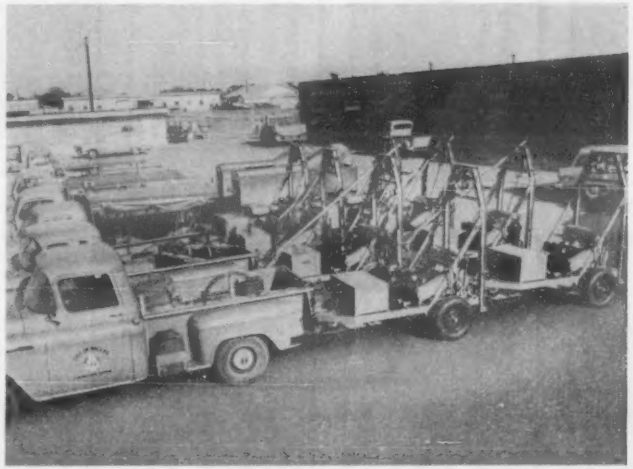

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